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ABSTRACT

This publication, the third in a series on drafting, is intended to strengthen students' competence in the specialized field of mechanical drafting. The text consists of instructional materials for both teacher and students, written in terms of student performance using measurable objectives. The course includes 11 units. Each instructional unit contains some or all of the basic components of a unit of instruction: performance objectives, suggested activities for teachers and students, information sheets, assignment sheets, job sheets, transparency masters, tests, and answers to the tests. Units are liberally illustrated and are planned for more than one lesson or class period of instruction. Information for the teacher includes an instructional/task analysis of mechanical drafting, a list of tools, material, and equipment needed, and a reference list. Topics covered in the 11 units are the following: orientation; tools and equipment; reference materials; layouts and working drawings; dimensioning and tolerancing; fasteners and hardware; presentation drawings; materials and specifications; manufacturing processes; sheet metal developments; and power transmission. (KC)

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ED219644

MECHANICAL DRAFTING

by

Gerald R. McClain

Developed by the

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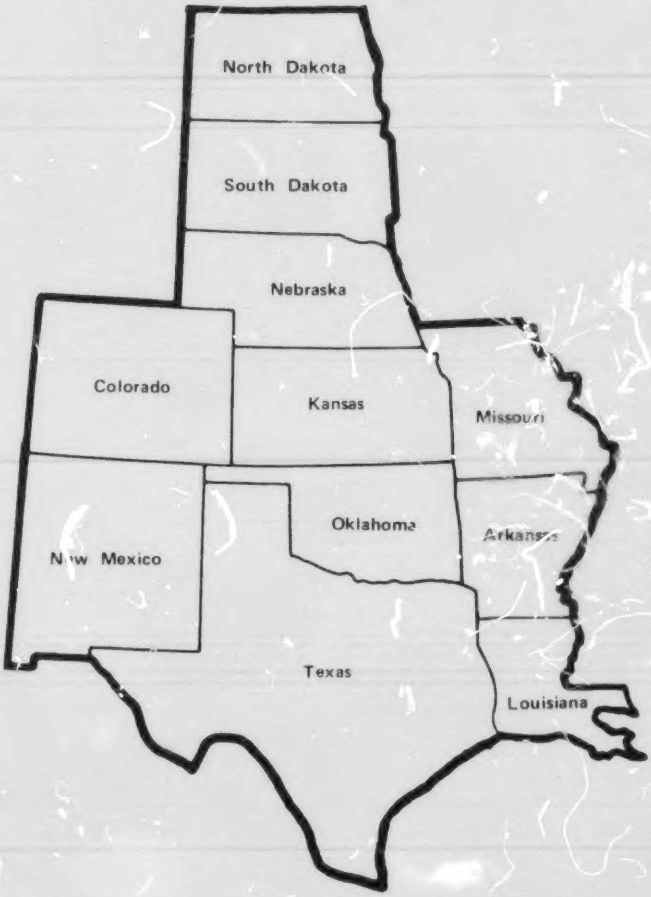
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TABLE OF CONTENTS

Unit I Orientation 1
Unit II Tools and Equipment 43
Unit III Reference Materials 139
Unit IV Layouts and Working Drawings 163
Unit V Dimensioning and Tolerancing 221
Unit VI Fasteners and Hardware 367
Unit VII Presentation Drawings 511
Unit VIII Materials and Specifications 579
Unit IX Manufacturing Processes 619
Unit X Sheet Metal Developments 691
Unit XI Power Transmission 851

FOREWORD

Mechanical Drafting is the third volume of a series of drafting materials being produced by the Mid-America Vocational Curriculum Consortium. *Basic Drafting: Book One* and *Basic Drafting: Book Two* comprise the basics necessary to be employed in a drafting occupation. This book, *Mechanical Drafting*, is designed to be used as a supplement to them so that the student can specialize.

The success of this publication is due, in large part, to the capabilities of the personnel who worked with its development. The technical writer has numerous years of industry as well as teaching and writing experience. Assisting him in his efforts were committee representatives who brought with them technical expertise and experience related to the classroom and to the trade. To assure that the materials would parallel the industry environment and to be accepted as a transportable basic teaching tool, other organizations and industry representatives were involved in the developmental phases of the manual. Appreciation is extended to them for their valuable contributions to the manual.

Instructional materials in this publication are written in terms of student performance using measurable objectives. This is an innovative approach to teaching that accents and augments the teaching/learning process. Criterion referenced evaluation instruments are provided for uniform measurement of student progress. In addition to evaluating recall information, teachers are encouraged to evaluate the other areas including process and product as indicated at the end of each instructional unit.

It is the sincere belief of the MAVCC personnel and all those members who served on the committee that this publication will allow the students to become better prepared and more effective members of the work force. If there is anything that we can do to help this publication become more useful to you, please let us know.

Merle Rudebusch, Chairman
Board of Directors
Mid-America Vocational
Curriculum Consortium

PREFACE

For many years those responsible for teaching drafting have felt a need for better quality materials to use in this area. To address this need, MAVCC has previously published two texts, *Basic Drafting, Book One* and *Basic Drafting, Book Two*. During the development of these basic materials, an even greater need was established, that being supplemental materials to help the students specialize in various areas of drafting. The team of teachers, industry representatives, teacher educators, and state level supervisors who had produced the original materials accepted this challenge and have now completed the first of the supplements. *Mechanical Drafting* is designed to be used in addition to the the first two publications, and is developed to strengthen a student's competence in the specialized field of mechanical drafting. This field is sometimes referred to as machine drafting, but because it involves the drafting of all mechanical devices, not only machines, we decided to entitle our text *Mechanical Drafting*.

This publication is designed to assist teachers in improving instruction. As this publication is used, it is hoped that the student performance will improve so the students will be better able to assume a role in their chosen occupation. Every effort has been made to make this publication basic, readable, and by all means, usable. Three vital parts of instruction have been intentionally omitted: motivation, personalization, and localization. These areas are left to the individual instructors who should capitalize on them. Only then will this publication really become a vital part of the teaching-learning process.

In addition, we would appreciate your help. We check for content quality, spelling, and typographical errors many times in the development of a manual. It is still possible, however, for an error to show up in a publication.

We are trying to provide you with the best possible curriculum materials and will certainly appreciate your help in detecting areas where possible corrections are needed to maintain the quality you want and deserve.

Ann Benson
Executive Director
Mid-America Vocational
Curriculum Consortium, Inc.

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USE OF THIS PUBLICATION

Instructional Units

Mechanical Drafting includes eleven units. Each instructional unit includes some or all of the basic components of a unit of instruction: performance objectives, suggested activities for teachers and students, information sheets, assignment sheets, job sheets, visual aids, tests, and answers to the test. Units are planned for more than one lesson or class period of instruction.

Careful study of each instructional unit by the teacher will help to determine:

A. The amount of material that can be covered in each class period
B. The skills which must be demonstrated
    1. Supplies needed
    2. Equipment needed
    3. Amount of practice needed
    4. Amount of class time needed for demonstrations
C. Supplementary materials such as pamphlets or filmstrips that must be ordered
D. Resource people who must be contacted

Objectives

Each unit of instruction is based on performance objectives. These objectives state the goals of the course, thus providing a sense of direction and accomplishment for the student.

Performance objectives are stated in two forms: unit objectives, stating the subject matter to be covered in a unit of instruction; and specific objectives, stating the student performance necessary to reach the unit objective.

Since the objectives of the unit provide direction for the teaching-learning process, it is important for the teacher and students to have a common understanding of the intent of the objectives. A limited number of performance terms have been used in the objectives for this curriculum to assist in promoting the effectiveness of the communication among all individuals using the materials.

Following is a list of performance terms and their synonyms which may have been used in this material:

Name	Identify	Describe
Label	Select	Define
List in writing	Mark	Discuss in writing
List orally	Point out	Discuss orally
Letter	Pick out	Interpret
Record	Choose	Tell how
Repeat	Locate	Tell what
Give	Label	Explain

Order
Arrange
Sequence
List in order
Classify
Divide
Isolate
Sort

Distinguish
Discriminate
Differentiate

Construct
Draw
Make
Build
Design
Formulate
Reproduce
Transcribe
Reduce
Increase
Figure

Demonstrate
Show your work
Show procedure
Perform an experiment
Perform the steps
Operate
Remove
Replace
Turn off/on
(Dis) assemble
(Dis) connect

Additional Terms Used
Evaluate
Complete
Analyze
Calculate
Estimate
Plan
Observe
Compare
Determine
Perform

Prepare
Make
Read
Tell
Teach
Converse
Lead
State
Write

Reading of the objectives by the student should be followed by a class discussion to answer any questions concerning performance requirements for each instructional unit.

Teachers should feel free to add objectives which will fit the material to the needs of the students and community. When teachers add objectives, they should remember to supply the needed information, assignment and/or job sheets, and criterion tests.

Suggested Activities for the Instructor:

Each unit of instruction has a suggested activities sheet outlining steps to follow in accomplishing specific objectives. Duties of instructors will vary according to the particular unit; however, for best use of the material they should include the following: provide students with objective sheet, information sheet, assignment sheets, and job sheets; preview filmstrips, make transparencies, and arrange for resource materials and people; discuss unit and specific objectives and information sheet; give test. Teachers are encouraged to use any additional instructional activities and teaching methods to aid students in accomplishing the objectives.

Information Sheets

Information sheets provide content essential for meeting the cognitive (knowledge) objectives in the unit. The teacher will find that the information sheets serve as an excellent guide for presenting the background knowledge necessary to develop the skill specified in the unit objective.

Students should read the information sheets before the information is discussed in class. Students may take additional notes on the information sheets.

Transparency Masters

Transparency masters provide information in a special way. The students may see as well as hear the material being presented, thus reinforcing the learning process. Transparencies may present new information or they may reinforce information presented in the information sheets. They are particularly effective when identification is necessary.

Transparencies should be made and placed in the notebook where they will be immediately available for use. Transparencies direct the class's attention to the topic of discussion. They should be left on the screen only when topics shown are under discussion.

Job Sheets

Job sheets are an important segment of each unit. The instructor should be able to and in most situations should demonstrate the skills outlined in the job sheets. Procedures outlined in the job sheets give direction to the skill being taught and allow both student and teacher to check student progress toward the accomplishment of the skill. Job sheets provide a ready outline for students to follow if they have missed a demonstration. Job sheets also furnish potential employers with a picture of the skills being taught and the performances which might reasonably be expected from a person who has had this training.

Assignment Sheets

Assignment sheets give direction to study and furnish practice for paper and pencil activities to develop the knowledges which are necessary prerequisites to skill development. These may be given to the student for completion in class or used for homework assignments. Answer sheets are provided which may be used by the student and/or teacher for checking student progress.

Test and Evaluation

Paper-pencil and performance tests have been constructed to measure student achievement of each objective listed in the unit of instruction. Individual test items may be pulled out and used as a short test to determine student achievement of a particular objective. This kind of testing may be used as a daily quiz and will help the teacher spot difficulties being encountered by students in their efforts to accomplish the unit objective. Test items for objectives added by the teacher should be constructed and added to the test.

Test Answers

Test answers are provided for each unit. These may be used by the teacher and/or student for checking student achievement of the objectives.

MECHANICAL DRAFTING
Instructional/Task Analysis

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
UNIT I: ORIENTATION	
	1. Terms and definitions
	2. Areas of specialization
	3. Industries that employ mechanical drafters
	4. Job titles and descriptions
	5. Steps in mechanical design and drafting work
	6. Duties of mechanical drafter
	7. Job classifications
	8. Related occupations
	9. Advantages and disadvantages of a mechanical drafting occupation
	10. Minimum qualifications
	11. Personality traits of drafter
	12. Related skills for drafter
	13. Evaluation areas
	14. Abbreviations
	15. Professional organizations
16. Interview a mechanical drafter	
17. Observe a mechanical drafter	
18. Evaluate a mechanical drawing	
UNIT II: TOOLS AND EQUIPMENT	
	1. Terms and definitions
	2. Mechanical templates
	3. Precision measuring instruments

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	4. Types of welding measuring instruments
	5. Types of scales
	6. Primary metric unit of measurement
	7. Hand calculator functions
	8. Types of keyboard sequences used in hand calculators
9. Read micrometer settings	
10. Read vernier calipers	
11. Measure with scales	
12. Compute mechanical drafting problems using a hand calculator	
13. Use a micrometer	
14. Use a vernier caliper	

UNIT III: REFERENCE MATERIALS

	1. Terms and definitions
	2. Product information literature
	3. Mechanical standards references
	4. Handbooks
	5. Standards in ANSI drafting manual
	6. ANSI standard parts
	7. ANSI miscellaneous standards
	8. ANSI metric standard fasteners references
9. Determine manufacturer of mechanical components from *Thomas Register*	

JOB TRAINING: What the Worker Should Be Able to Do
(Psychomotor)

RELATED INFORMATION: What the Worker Should Know
(Cognitive)

10. Write a letter requesting product literature for mechanical components

11. Write a technical report using reference materials

UNIT IV: LAYOUTS AND WORKING DRAWINGS

1. Terms and definitions
2. Title forms
3. Information or revision blocks
4. Information on a bill of material/parts list
5. Stages of design process
6. Design layouts
7. Elements of design layout sketch
8. Parts of detail drawing
9. Parts of assembly drawing
10. Information found on outline or installation assemblies
11. Information found on welding assembly drawings
12. Characteristics of forging drawings
13. Information found on a pattern or casting drawing

14. Draw a design layout
15. Draw a set of detail drawings
16. Draw an assembly drawing
17. Complete a detailed title block and revision block
18. Complete a parts list
19. Make a drawing revision

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

RELATED INFORMATION: What the Worker Should Know (Cognitive)

UNIT V: DIMENSIONING AND TOLERANCING

1. Terms and definitions
2. Size and location dimensions for a geometric shape
3. Mating dimensions in an assembly drawing
4. Numerical control dimensioning
5. Fits for inch and metric units
6. Limits in inch units using basic hole system
7. Limits in metric units using basic hole system
8. Tolerance ranges for shop processes
9. Hole size limits for standard dowels
10. Limit dimensions for interchangeability of parts
11. Limit dimensions for intermediate parts
12. Symbols for tolerance and form
13. Symbols for position and form
14. Positional tolerancing
15. Angular tolerances
16. Surface quality specifications
17. Surface quality symbols
18. Surface quality notes
19. Lay symbols

JOB TRAINING: What the Worker Should Be Able to Do
(Psychomotor)

RELATED INFORMATION: What the Worker Should Know
(Cognitive)

20. Dimension an object completely
21. Calculate and dimension clearance fit tolerances using standard fit tables
22. Calculate and dimension interference fit tolerances using standard fit tables
23. Calculate and assign tolerances to mating parts using standard fit tables
24. Calculate and dimension hole size limits for standard dowels
25. Dimension an object using position and form tolerances
26. Determine ranges of motion of limbs and spaces required for a person

UNIT VI: FASTENERS AND HARDWARE

1. Terms and definitions
2. Types of fasteners
3. Applications of screw threads
4. Screw threads nomenclature
5. Screw thread profiles
6. Lead of thread
7. Screw thread symbols
8. Classes of fit for unified threads
9. Classes of fit for metric threads
10. Parts of thread notes
11. Conventional representations of pipe threads
12. Types of threaded removable fasteners
13. Shapes of bolts and nuts

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

RELATED INFORMATION: What the Worker Should Know (Cognitive)

14. Types of locknuts and locking devices
15. Types of standard cap screws
16. Types of machine screws
17. Set screw heads and points
18. Miscellaneous bolts and screws
19. Standard large and small rivets
20. Rivet symbols
21. Advantages of plastic fasteners over metal fasteners
22. Devices to lock components on a shaft
23. Types of springs
24. Types of spring clips
25. Types of keys
26. Types of machine pins
27. Washers
28. Applications of inserts
29. Types of lock washers
30. Uses for spring washer designs
31. Quick opening and locking devices
32. Miscellaneous machine elements
33. Advantages of different fasteners
34. Types of welded joints
35. Parts of a welding symbol
36. Basic arc and gas weld symbols

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	37. Supplementary welding symbols
	38. Welding dimensions for a fillet weld
	39. Resistance welding symbols
	40. Using adhesives for bonding materials
	41. Joint design considerations for adhesive bonding
42. Construct thread symbols	
43. Construct bolts, screws, and nuts	
44. Construct an assembly containing various fasteners	
45. Construct a welded assembly drawing	
46. Construct spring drawings to include specifications	
47. Construct keys in assembled positions	
48. Write specifications for hardware from vender catalogs	

UNIT VII: PRESENTATION DRAWINGS

	1. Terms and definitions
	2. Types of presentation sketches
	3. Steps of sketching
	4. Ellipse construction
	5. Shading techniques
	6. Types of axonometric drawings
	7. Oblique drawings
	8. Parts of exploded assembly presentation drawings
	9. Special requirements for patent drawings

JOB TRAINING: What the Worker Should Be Able to Do
(Psychomotor)

RELATED INFORMATION: What the Worker Should Know
(Cognitive)

10. Shade pictorials

11. Construct conceptual presentation sketches

12. Construct design sketches

13. Construct a dimetric presentation drawing

14. Construct an oblique presentation drawing

15. Construct a two point presentation perspective of an object

16. Construct an exploded assembly presentation drawing

UNIT VIII: MATERIALS AND SPECIFICATIONS

1. Terms and definitions

2. Specifications found on mechanical drawings

3. Heat treatments for metals

4. Surface hardening treatments for metals

5. Forms of carbon steel

6. Categories of pipe

7. Specifications for tubing callouts

8. Specifications for structured steel shapes

9. Standard mill forms of materials

10. Metal properties

11. Factors to consider in selecting materials

12. Types and kinds of ferrous manufacturing metals

JOB TRAINING: What the Worker Should Be Able to Do
(Psychomotor)

RELATED INFORMATION: What the Worker Should Know
(Cognitive)

13. Parts of the steel numbering system

14. Copper type metals

15. Condition of aluminum

16. Types of plastic materials

17. Refractory materials

18. Determine wire and sheet metal size from gage number

19. Select materials from a materials stock book

UNIT IX: MANUFACTURING PROCESSES

1. Terms and definitions
2. Purposes of manufacturing processes
3. Types of drawings
4. Casting terms
5. Design procedures for casting
6. Pattern and machine dimensions
7. Design procedures for a forging
8. Design procedures for a welded assembly
9. Machine processes
10. Numerical control machinery
11. Plastics
12. Sheet metal processing
13. Sheet metal hems and joints

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

RELATED INFORMATION: What the Worker Should Know (Cognitive)

14. Calculate bend allowance for sheet metal
15. Design a casting part
16. Design a forging part
17. Design a welded part
18. Design a thermoplastic part

UNIT X: SHEET METAL DEVELOPMENTS

1. Terms and definitions
2. Visualization
3. Constructing an auxiliary view
4. True length lines and true sizes of three view drawings
5. Point views of lines and edge views of planes
6. Characteristics of rotation
7. Elements of single curved surfaces
8. Finding intersections of surfaces
9. Groups of developments

10. Calculate bend allowance
11. Label points, lines, and planes in views
12. Identify true lengths and types of lines
13. Identify true sizes and types of planes
14. Construct lengths of lines and true sizes of planes using auxiliary views
15. Construct true lengths of lines by rotation
16. Construct true sizes of planes by rotation
17. Locate elements of single curved surfaces

JOB TRAINING: What the
Worker Should Be Able to Do
(Psychomotor)

18. Construct intersections of surfaces
19. Construct intersections of surfaces using two-view method
20. Construct radial line developments
21. Construct parallel line developments
22. Construct special developments using triangulation

RELATED INFORMATION: What
the Worker Should Know
(Cognitive)

UNIT XI: POWER TRANSMISSION

1. Terms and definitions
2. Advantages of chain drives and gear drives
3. Advantages of chain drives and belt drives
4. Steps for selecting a V-belt drive
5. Types of power transmission chains
6. Types of gears
7. Parts of gear teeth
8. Parts of pinion and gear
9. Cutting data needed for spur gear drawings
10. Parts of a bevel gear
11. Cutting data needed for bevel gears
12. Cutting data needed for worm and worm wheel
13. Gear ratio
14. Gear rotation

JOB TRAINING: What the Worker Should Be Able to Do
(Psychomotor)

24. Construct a spur gear drawing
25. Construct a bevel gear
26. Construct a worm and worm gear
27. Calculate gear ratios
28. Determine gear rotation
29. Calculate gear speeds
30. Construct a cam drawing
31. Select a chain drive
32. Select a V-belt drive
33. Select types of bearings from handbooks

RELATED INFORMATION: What the Worker Should Know
(Cognitive)

15. Gear speed
16. Types of couplings
17. Types of bearings
18. Cam nomenclature
19. Types of cam followers
20. Types of cam motions
21. Hydraulic nomenclature
22. Pneumatic components
23. Air circuit components

Tools, Materials, and Equipment List

Triangles 45°, 30° 60°
Compass
Divider
Protractor
Irregular curve
Drafting machine with scales or
Parallel bar or T-square with adjustable triangle
Drawing media
Drawing surface or table
Drafting tape
Drawing pencils
Lead holder
Lead
Lead pointer
Paper towel or cleaning cloth
Nonabrasive hand eraser
Lettering guide for guidelines
Scale wrench
Mechanical Engineer Scale
Machinists steel rules
Metric scale
Standard fit tables
ANSI Drafting Standards Manual

(NOTE: Micrometers and vernier scale calipers need to be available for use in Unit I, "Tools and Equipment.")

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ORIENTATION
UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to list job opportunities within the mechanical drafting profession and recognize the qualifications and performance standards for positions in the profession. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to orientation with the correct definitions.
2. Define mechanical drafting.
3. List areas of specialization in mechanical drafting.
4. List industries that employ mechanical drafters.
5. Match job titles with the correct job descriptions.
6. Arrange in order the steps in mechanical design and drafting work.
7. Select duties of a mechanical drafter.
8. Match job classifications with the correct responsibilities within a manufacturing structure.
9. List related occupations for a mechanical drafter.
10. Distinguish between the advantages and disadvantages of a mechanical drafting occupation.
11. Match mechanical drafting positions with the correct minimum qualifications.
12. List important personality traits for a mechanical drafter.
13. Select important related skills for a mechanical drafter.
14. Complete a list of evaluation areas for drafters.
15. Select evaluation areas for mechanical drawings.
16. Define abbreviations of professional organizations for mechanical drafters and designers.

17. Select advantages of joining and/or participating in professional organizations.

18. Demonstrate the ability to:
    a. Interview a mechanical drafter.
    b. Observe a mechanical drafter.
    c. Evaluate a mechanical drawing.

ORIENTATION
UNIT I

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and assignment sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Have students role play and interview each other if it is not possible for them to interview a mechanical drafter for Assignment Sheet #1.

VII. Have students set up one appointment with a mechanical drafter for use with both Assignment Sheets #1 and #2.

VIII. Provide actual mechanical drawings for use with Assignment Sheet #3.

IX. Discuss in detail the advantages and disadvantages of being a mechanical drafter.

X. Invite speakers who have experience as mechanical drafters, checkers, and designers to speak to the class about their jobs.

XI. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet

  B. Information sheet

  C. Transparency masters

    1. TM 1--Types of Mechanical Drafting

    2. TM 2--Types of Mechanical Drafting (Continued)

    3. TM 3--Industries That Employ Mechanical Drafters

    4. TM 4--Promotional Opportunities

    5. TM 5--Check List for Evaluating a Mechanical Drafter

    6. TM 6--Check List for Mechanical Drawings

D. Assignment sheets

1. Assignment Sheet #1--Interview a Mechanical Drafter

2. Assignment Sheet #2--Observe a Mechanical Drafter

3. Assignment Sheet #3--Evaluate a Mechanical Drawing

E. Test

F. Answers to test

II. References:

A. Earle, James H. *Engineering Design Graphics.* Reading, Mass: Addison-Wesley Publishing Co., 1978.

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ORIENTATION
UNIT I

INFORMATION SHEET

I. Terms and definitions

   A. Technological team--Craftworkers, technicians, technologists, engineers, and scientists organized to solve a complex technical problem in a manufacturing environment

   B. Technologist--Specialist in the technical details of solving an engineering problem; works as liaison between engineer and technician

   (NOTE: A technologist sometimes works in the place of an engineer but is not a professional engineer.)

   C. Designer--Engineer, technologist, or technician who has inventiveness and technical specialty

   D. Product design--Design of a product or redesign of a product for consumers

   E. Manufacturing design--Design of tools, fixtures, and machines for manufacturing a product

   F. Mechanical designer--Technician, technologist, or engineer specialist that works in either product design and/or manufacturing design

   (NOTE: Whether this person is a technician, technologist, or engineer depends upon the individual's experience and level of education.)

   G. Level of technology--Classification of industries according to level of engineering complexity

   (NOTE: A low level technology industry may be involved with simple mechanical parts, such as farm implements. A high level technology industry may be involved with complicated mechanical, hydraulic, or electronic parts, such as a space station.)

II. Definition of mechanical drafting--Form of drafting of mechanical parts and assemblies so that a product or manufacturing process can be produced

III. Areas of specialization in mechanical drafting (Transparencies 1 and 2)

   A. Product related

      1. Machines

      2. Aerospace

      3. Structural

INFORMATION SHEET

4. Piping
5. Pressure vessel
6. Computer graphics
7. Communication
8. Sheet metal
9. Aircraft
10. Electrical power
11. Farm machinery
12. Mechanical power
13. Transportation
14. Power generation
15. Military equipment
16. Ships
17. Propulsion systems

B. Manufacturing related

1. Machines
2. Tool design
3. Production design
4. Industrial electronics
5. Instrumentation
6. Numerical control
7. Plant layout
8. Estimating
9. Systems
10. Power systems

IV. Industries that employ mechanical drafters (Transparency 3)

A. Transportation

B. Oil

INFORMATION SHEET

- C. Manufacturing
- D. Communication
- E. Pipeline
- F. Material fabrication
- G. Electronics
- H. Military
- I. Aerospace
- J. Farm machinery
- K. Power generation
- L. Ship building

V. Job titles and job descriptions (Transparency 4)

- A. Trainee
    1. Traces or copies drawings made by others
    2. Revises drawings working from instructions
    3. Repairs or redraws damaged drawings
    4. Requires frequent supervision
- B. Junior drafter
    1. Corrects and revises drawings
    2. May make simple detail and assembly drawings
    3. Makes sketches
    4. Requires some supervision
- C. Drafter
    1. Draws details and assembly drawings
    2. Works with handbooks and reference materials
    3. Makes routine calculations
    4. Makes sketches and field notes
    5. Is completely familiar with drafting standards

INFORMATION SHEET

D. Senior drafter

   1. Handles design drafting detail assignments
   2. Exercises considerable judgment in layout
   3. Makes or reviews many calculations
   4. Has some supervisory duties

E. Checker

   1. Is an experienced drafter
   2. Checks all final drawings for errors
   3. Is directly responsible for errors
   4. Routes drawings through the department

F. Design drafter technician

   1. Works from engineering notes and specifications
   2. Does calculations
   3. Has thorough knowledge of accepted design concepts
   4. Works with statics, strength of material, machine design, kinematics, and mechanisms
   5. Has increased supervisory duties
   6. Handles complete design assignment with minimum supervision
   7. Generally has a two-year associate degree or equivalent

G. Design technologist

   1. Works with engineering staff
   2. Is a thoroughly experienced drafter
   3. Works with statics, strength of material, machine design, kinematics, and mechanisms
   4. Generally has a two or four-year college degree in mechanical design technology or design and drafting technology
   5. Has increased supervisory duties

INFORMATION SHEET

H. Senior design technologist

(NOTE: The senior design technologist may be called a product engineer or manufacturing engineer and may be the manager of the mechanical design and drafting department.)

1. Has several years experience
2. Coordinates production deadlines and cost analysis
3. Generally has a four-year college degree in mechanical design technology or engineering
4. Works with industrial designers and others responsible for social and environmental impact
5. Has increased supervisory duties

I. Chief design drafter

(NOTE: The chief design drafter may be the manager of the mechanical design and drafting department. Usually these drafters have worked their way up through the department.)

1. Responsible for all design and drafting in a company
2. Is in charge of hiring and firing
3. Sets work schedules, company drafting and design standards, and work loads
4. Generally has a four-year college degree in mechanical design technology or engineering
5. Responsible for budgeting and purchasing for department
6. Has increased supervisory duties

J. Computer-aided design drafter

1. Has all the skills of drafter
2. Has typing skills if input is by keyboard
3. Has two-year associate degree or equivalent

K. Computer-aided designer

1. Has all the skills of drafter and designer
2. Has computer programming skills
3. Has two or four-year college degree in mechanical design technology or design drafting technology

INFORMATION SHEET

VI. Steps in mechanical design and drafting work

- A. Preliminary design layout and/or rough sketches
- B. Set of working drawings
- C. Parts list and/or materials list and specifications
- D. Checking
- E. Corrections
- F. Engineer's approval
- G. Drawing release for production
- H. Revisions
- I. Prints made and sent to fabricators

VII. Duties of a mechanical drafter

- A. Read blueprints and interpret engineering sketches
- B. Prepare working drawings
- C Compile bill of materials and/or parts list
- D. Use handbooks and reference materials to determine specifications and correct data concerning materials to be used
- E. Make necessary revisions and corrections on drawings that have been completed
- F. Maintain neat and accurate job files for jobs in progress
- G. Use all drafting equipment for mechanical drafters
- H. Maintain accurate file system for drawings

  (NOTE: In large companies this may be centralized, but in many smaller firms it is the direct responsibility of drafters to maintain the drawing files.)
- I. Establish working relationships with other personnel
- J. Dress and act in a manner acceptable to associates

INFORMATION SHEET

VIII. Job classifications and responsibilities within a manufacturing structure

  A. Craftworkers--Production, skill trades

  B. Technicians--Design, supervision, drafting, development, manufacturing

  C. Non-registered technologists/engineers--Design, supervision, drafting, development, manufacturing

  D. Registered engineers--Design, management

IX. Related occupations for a mechanical drafter

  A. Estimator-cost analyst

  B. Inspector for quality control

  C. Fabricator of prototypes and models

  D. Manufacturing technician

  E. Engineering aide

  F. Sales representative for mechanical products

  G. Technical illustrator

  H. Numerical control programmer

  I. Computer-aided drafter or designer

X. Advantages and disadvantages of a mechanical drafting occupation

  A. Advantages

    1. Clean indoor working conditions
    2. Open job market
    3. Most versatile and largest demand of all drafting areas
    4. Good fringe benefit package
    5. Much overtime available
    6. Sense of self-satisfaction and pride
    7. Good chance for advancement into higher paying occupations
    8. Variety of challenging assignments
    9. Opportunity to work alone on some projects
    10. Individual drawing table and desk

INFORMATION SHEET

B. Disadvantages

1. Relatively confined area
2. Long hours at times of peak production
3. Responsibility to both management and production
4. Rigid accountability for accurate work
5. Knowledge of many technical fields required
6. Competition for raises and promotion
7. Very little physical exercise
8. Rigid time limits for doing work

XI. Mechanical drafting positions and minimum qualifications (Transparency 4)

A. Trainee

1. High school diploma, or be successfully working toward one
2. Course work in vocational drafting

   (NOTE: There is often a minimum grade point average that is required in this course work.)

3. One year of algebra and one year of geometry
4. Good character references
5. Good school attendance record

B. Drafter

1. High school diploma
2. Two or more years of vocational drafting

   (NOTE: There is often a minimum grade point average that is required in this course work.)

3. One or two years of algebra, one year of geometry, and one year of trigonometry
4. Good character references
5. Successful completion of an in-company training period

   (NOTE: In some companies this could be as long as one year.)

INFORMATION SHEET

C. Design drafter or computer-aided design drafter

   1. Associate degree or equivalent in mechanical design technology or design and drafting technology

   2. Three years of drafting experience

   3. Good working credentials

D. Design technologist or computer-aided designer

   1. Associate degree or equivalent or bachelor's degree in mechanical design technology, design and drafting technology, or mechanical engineering

   2. Five years of drafting experience in specialty area in place of bachelor's degree

   3. Good working credentials

   (NOTE: They may have engineer in their title, but they are not required to be licensed engineers.)

E. Licensed engineer

   1. Bachelor's or master's degree in engineering (4-5 years)

   2. Successful completion of state examination for engineering specialty area

   3. Apprenticeship with 4-5 years of experience

XII. Important personality traits for a mechanical drafter

A. Ability to listen to and follow instructions well

B. Punctuality

C. Dependability

D. Ability to accept constructive criticism

E. Willingness to continue education

F. Ability to work quietly and patiently at detailed work for long hours

G. Flexibility to work alone at times and with others when needed

(NOTE: In addition to personality, personal appearance is very important.)

INFORMATION SHEET

XIII. Important related skills for a mechanical drafter

- A. Speed
- B. Ability to operate drafting equipment correctly
- C. Manual dexterity
- D. Communication skills

  (NOTE: This should include language arts skills such as grammar, punctuation, and spelling.)
- E. Knowledge of materials, components, and manufacturing processes
- F. Math skills
- G. Ability to do neat, legible lettering

XIV. Evaluation areas for drafters (Transparency 5)

- A. Speed
- B. Accuracy
- C. Completeness
- D. Ability to get along with others
- E. Ability to work unsupervised
- F. Ability to conserve materials and man hours

XV. Evaluation areas for mechanical drawings (Transparency 6)

- A. Accuracy
- B. Linework
- C. Lettering
- D. Overall neatness
- E. Dimensioning
- F. Reproducibility
- G. Spelling and use of abbreviations

INFORMATION SHEET

XVI. Abbreviations of professional organizations for mechanical drafters and designers

- A. AIDD--American Institute of Design and Drafting
- B. SME--Society of Manufacturing Engineers
- C. ASME--American Society of Mechanical Engineers
- D. AIIE--American Institute of Industrial Engineers
- E. AIAA--American Institute of Aeronautics and Astronautics
- F. JETS--Junior Engineering Technical Society
- G. ICET--Institute for Certification of Engineering Technicians
- H. NCGA--National Computer Graphics Association

(NOTE: Some of these organizations have student chapters.)

XVII. Advantages of joining and/or participating in professional organizations

- A. Find out about job opportunities
- B. Keep up with changing technology
- C. Make contacts and new friends within the industry to find job openings
- D. Obtain personal library of technical reference material
- E. Obtain certification credentials

(NOTE: Many of these credentials are recognized nationally. These can be extremely important if a person wants to change localities within the United States.)

Types of Mechanical Drafting

A. Product Related

1. Machines
2. Aerospace
3. Structural
4. Piping
5. Pressure Vessel
6. Computer Graphics
7. Communications
8. Sheet Metal
9. Aircraft
10. Electrical Power
11. Farm Machinery
12. Mechanical Power
13. Transportation
14. Power Generation
15. Military Equipment
16. Ships
17. Propulsion Systems

Types of Mechanical Drafting
(Continued)

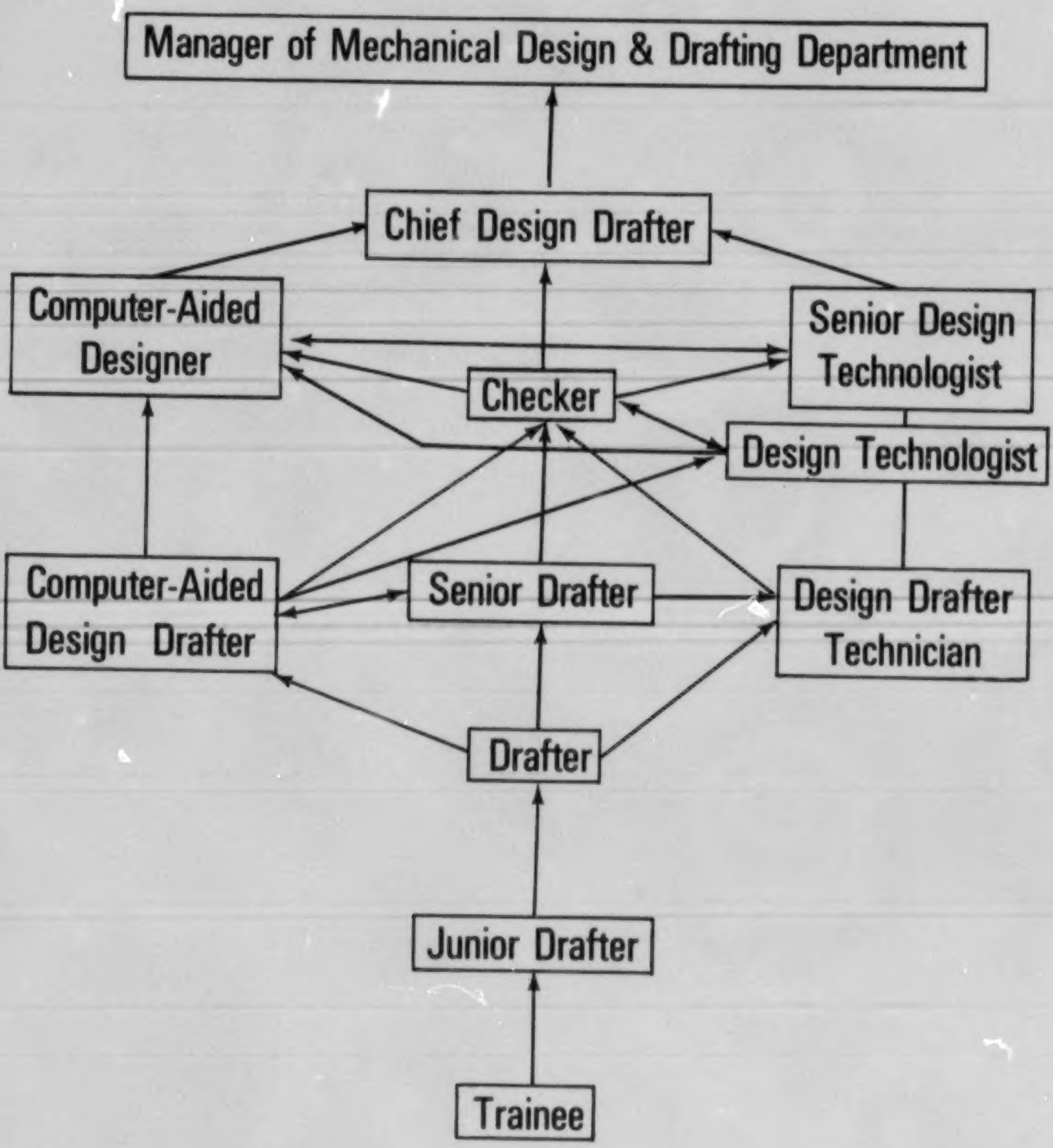
B. Manufacturing Related

1. Machines
2. Tool Design
3. Production Design
4. Industrial Electronics
5. Instrumentation
6. Numerical Control
7. Plant Layout
8. Estimating
9. Systems
10. Power Systems

Industries That Employ Mechanical Drafters

A. Transportation
B. Oil
C. Manufacturing
D. Communication
E. Pipeline
F. Material Fabrication
G. Electronics
H. Military
I. Aerospace
J. Farm Machinery
K. Power Generation
L. Ship Building

Promotional Opportunities


Manager of Mechanical Design & Drafting Department
Chief Design Drafter
Computer-Aided Designer
Senior Design Technologist
Checker
Design Technologist
Computer-Aided Design Drafter
Senior Drafter
Design Drafter Technician
Drafter
Junior Drafter
Trainee

Check List for Evaluating a Mechanical Drafter

A. Speed

B. Accuracy

C. Completeness

D. Ability to Get Along with Others

E. Ability to Work Unsupervised

F. Ability to Conserve Materials
and Man Hours

Check List for Mechanical Drawings

A. Accuracy

B. Linework

C. Lettering

D. Overall Neatness

E. Dimensioning

F. Reproducibility

G. Spelling and
Use of Abbreviations

ORIENTATION
UNIT I

ASSIGNMENT SHEET #1--INTERVIEW A MECHANICAL DRAFTER

Directions: Make an appointment with a mechanical drafter who is presently employed in that capacity. Ask the following questions and record the answers in the blanks provided.

1. What is your career title? ______________________________

____

2. What tasks do you perform on the job? ______________________

____

____

3. What educational training and occupational experience is required for this job?

____

____

4. What personality traits are most important in your field? __________

____

____

5. What skills and knowledge are required in this occupation? __________

____

____

6. What is the approximate starting salary of workers in your occupation? ______

____

____

7. What is the employment outlook for the future in this career? ________

____

____

ASSIGNMENT SHEET #1

8. What are the possibilities for advancement in this field? ______________________

____

____

9. What is your favorite part of this job? ______________________

____

____

10. What is your least favorite part of the job? ______________________

____

____

ORIENTATION
UNIT I

ASSIGNMENT SHEET #2--OBSERVE A MECHANICAL DRAFTER

Directions: After you finish Assignment Sheet #1, ask the mechanical drafter if you could watch quietly for about an hour in order to observe the drafter's work habits. Make comments in the blanks provided, and rate in the following areas:

	EXCELLENT	GOOD	FAIR
1. Speed ____________________ ____________________			
2. Accuracy ____________________ ____________________			
3. Completeness ____________________ ____________________			
4. Ability to get along with others ____________________ ____________________			
5. Ability to work unsupervised ____________________ ____________________			

ASSIGNMENT SHEET #2

	EXCELLENT	GOOD	FAIR
6. Ability to conserve materials and man hours			

(NOTE: You may not be able to give a fair evaluation for all areas in only one hour, but rate what you see to the best of your ability.)

ORIENTATION
UNIT I

ASSIGNMENT SHEET #3--EVALUATE A MECHANICAL DRAWING

Directions: Evaluate a mechanical drawing of a fellow student or one provided by the instructor. Make comments in the blanks provided and evaluate in the following areas:

	EXCELLENT	GOOD	FAIR
1. Accuracy ____________________ ____________________			
2. Linework ____________________ ____________________			
3. Lettering ____________________ ____________________			
4. Overall neatness ____________________ ____________________			
5. Dimensioning ____________________ ____________________			

ASSIGNMENT SHEET #3

	EXCELLENT	GOOD	FAIR
6. Reproducibility			
7. Spelling and use of abbreviations			

(NOTE: You may want to actually reproduce the drawing, or ask the instructor how well it would reproduce.)

ORIENTATION
UNIT I

NAME ______________________________

TEST

1. Match the terms on the right with the correct definitions.

______ a. Engineer, technologist, or technician who has inventiveness and technical specialty

______ b. Craftworkers, technicians, technologists, engineers, and scientists organized to solve a complex technical problem in a manufacturing environment

______ c. Design of a product or redesign of a product for consumers

______ d. Technician, technologist, or engineer specialist that works in either product design and/or manufacturing design

______ e. Specialist in the technical details of solving an engineering problem; works as liaison between engineer and technician

______ f. Design of tools, fixtures, and machines for manufacturing a product

______ g. Classification of industries according to level of engineering complexity

1. Product design
2. Mechanical designer
3. Technologist
4. Level of technology
5. Technological team
6. Designer
7. Manufacturing design

2. Define mechanical drafting.

____

____

____

3. List eight areas of specialization in mechanical drafting.

a. ____

b. ____

c. ____

d. ____

e. ______________________________

f. ______________________________

g. ______________________________

h. ______________________________

4. List six industries that employ mechanical drafters.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

5. Match the job titles on the right with the correct job descriptions.

______a. Coordinates production deadlines and cost analysis

______b. Handles complete design assignment with minimum supervision

______c. Traces or copies drawings made by others

______d. Exercises considerable judgment in layout

______e. May make simple detail and assembly drawings

______f. Is completely familiar with drafting standards

______g. Works with statics, strength of material, machine design, kinematics, and mechanisms

______h. Checks all final drawings for errors

______i. Has typing skills if input is by keyboard

______j. Is in charge of hiring and firing

______k. Has computer programming skills

1. Trainee
2. Junior drafter
3. Drafter
4. Senior drafter
5. Checker
6. Design drafter technician
7. Design technologist
8. Senior design technologist
9. Chief design drafter
10. Computer-aided design drafter
11. Computer-aided designer

6. Arrange in order the steps in mechanical design and drafting work by placing the correct sequence numbers in the appropriate blanks.

______a. Drawing release for production

______b. Revisions

______c. Engineer's approval

______d. Corrections

______e. Prints made and sent to fabricators

______f. Checking

______g. Set of working drawings

______h. Parts list and/or materials list and specifications

______i. Preliminary design layout and/or rough sketches

7. Select duties of a mechanical drafter by placing an "X" in the appropriate blanks.

______a. Visit construction site

______b. Make necessary revisions and corrections on drawings that have been completed

______c. Compile bill of materials and/or parts list

______d. Read blueprints and interpret engineering sketches

______e. Supervise construction crew

______f. Prepare working drawings

______g. Type office correspondence

______h. Use all drafting equipment for mechanical drafters

8. Match the job classifications on the right with the correct responsibilities within a manufacturing structure.

______a. Design, supervision, drafting, development, manufacturing

______b. Design, management

______c. Production, skill trades

1. Registered engineers
2. Non-registered technologists/engineers
3. Technicians
4. Craftworkers

9. List five related occupations for a mechanical drafter.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

10. Distinguish between the advantages and disadvantages of a mechanical drafting occupation by placing an "X" next to the advantages.

______a. Relatively confined area

______b. Open job market

______c. Good chance for advancement into higher paying occupations

______d. Very little physical exercise

______e. Responsibility to both management and production

______f. Much overtime available

______g. Good fringe benefit package

11. Match the mechanical drafting positions on the right with the correct minimum qualifications.

(NOTE: Some qualifications can be answered by more than one position.)

______a. Course work in vocational drafting

______b. Successful completion of state examination for engineering specialty area

______c. Three years of drafting experience

______d. Five years of drafting experience in specialty area in place of bachelor's degree

______e. Associate degree or equivalent in mechanical design technology or design and drafting technology

______f. Bachelor's or master's degree in engineering

1. Trainee
2. Drafter
3. Design drafter or computer-aided design drafter
4. Design technologist or computer-aided designer
5. Licensed engineer

12. List four important personality traits for a mechanical drafter.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

13. Select important related skills for a mechanical drafter by placing an "X" in the appropriate blanks.

_____a. Slow

_____b. Ability to operate drafting equipment correctly

_____c. Manual dexterity

_____d. Ability to do survey work

_____e. Knowledge of materials, components, and manufacturing processes

_____f. Math skills

_____g. Ability to do neat, legible lettering

14. Complete the following list of evaluation areas for drafters.

a. Speed

b. ______________________________

c. Completeness

d. ______________________________

e. Ability to work unsupervised

f. Ability to conserve materials and man hours

15. Select evaluation areas for mechanical drawings by placing an "X" in the appropriate blanks.

_____a. Lettering

_____b. Cleverness of design

_____c. Linework

_____d. Dimensioning

16. Define the following abbreviations of professional organizations for mechanical drafters and designers.

a. AIIE-- ______________________________

b. SME-- ______________________________

c. AIDD-- ______________________________

d. ICET-- ______________________________

17. Select advantages of joining and/or participating in professional organizations by placing an "X" in the appropriate blanks.

    _____a. Make contacts and new friends within the industry to find job openings

    _____b. Obtain certification credentials

    _____c. Requires dues to be paid for membership

    _____d. Keep up with changing technology

    _____e. May take away from family time once a month

18. Demonstrate the ability to:

    a. Interview a mechanical drafter.

    b. Observe a mechanical drafter.

    c. Evaluate a mechanical drawing.

    (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

ORIENTATION
UNIT I

ANSWERS TO TEST

1. a. 6
   b. 5
   c. 1
   d. 2
   e. 3
   f. 7
   g. 4

2. Mechanical drafting--Form of drafting of mechanical parts and assemblies so that a product or manufacturing process can be produced

3. Any eight of the following:

   a. Machines
   b. Aerospace
   c. Structural
   d. Piping
   e. Pressure vessel
   f. Computer graphics
   g. Communication
   h. Sheet metal
   i. Aircraft
   j. Electrical power
   k. Farm machinery
   l. Mechanical power
   m. Transportation
   n. Power generation
   o. Military equipment
   p. Ships
   q. Propulsion systems
   r. Tool design
   s. Production design
   t. Industrial electronics
   u. Instrumentation
   v. Numerical control
   w. Plant layout
   x. Estimating
   y. Systems
   z. Power systems

4. Any six of the following:

   a. Transportation
   b. Oil
   c. Manufacturing
   d. Communication
   e. Pipeline
   f. Material fabrication
   g. Electronics
   h. Military
   i. Aerospace
   j. Farm machinery
   k. Power generation
   l. Ship building

5. a. 8
   b. 6
   c. 1
   d. 4
   e. 2
   f. Any except 1 or 2
   g. 6, 7
   h. 5
   i. 10 or 11
   j. 9
   k. 11

6. a. 7
   b. 8
   c. 6
   d. 5
   e. 9
   f. 4
   g. 2
   h. 3
   i. 1

7. b, c, d, f, h

8. a. 2, 3
   b. 1
   c. 4

9. Any five of the following:

a. Estimator-cost analyst
b. Inspector for quality control
c. Fabricator of prototypes and models
d. Manufacturing technician
e. Engineering aide
f. Sales representative for mechanical products
g. Technical illustrator
h. Numerical control programmer
i. Computer-aided drafter or designer

10. b, c, f, g

11. a. 1,2 c. 3 e. 3, 4
b. 5 d. 4 f. 5

12. Any four of the following:

a. Ability to listen to and follow instructions well
b. Punctuality
c. Dependablity
d. Ability to accept constructive criticism
e. Willingness to continue education
f. Ability to work quietly and patiently at detailed work for long hours
g. Flexibility to work alone at times and with others when needed

13. b, c, e, f, g

14. b. Accuracy
d. Ability to get along with others

15. a, c, d

16. a. American Institute of Industrial Engineers
b. Society of Manufacturing Engineers
c. American Institute of Design and Drafting
d. Institute for Certification of Engineering Technicians

17. a, b, d

18. Evaluated to the satisfaction of the instructor

TOOLS AND EQUIPMENT
UNIT II

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify tools and equipment and use the equipment to solve problems. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

(NOTE: Students are expected to have covered units on tools, equipment, and scales from *Basic Drafting, Book One* before attempting this unit.)

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to tools and equipment with the correct definitions.
2. Complete a list of mechanical templates.
3. Match machinist precision measuring instruments with the correct functions.
4. Identify types of welding measuring instruments.
5. Identify types of scales used in mechanical drafting.
6. Name the primary metric unit of measurement used in mechanical drafting.
7. Classify the scales used in mechanical drafting.
8. Complete a list of hand calculator functions.
9. Distinguish between the types of keyboard sequences used in hand calculators.
10. Demonstrate the ability to:
    a. Read micrometer settings.
    b. Read vernier calipers.
    c. Measure with scales.
    d. Compute mechanical drafting problems using a hand calculator.
    e. Use a micrometer.
    f. Use a vernier caliper.

TOOLS AND EQUIPMENT
UNIT II

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Invite a machinist and/or welder to class to discuss measuring devices.

VIII. Display several types of tools and related items used in various machine and welding shops.

IX. Allow students to measure with devices.

X. Discuss the importance of accuracy and precision with students.

XI. Use a computer, if available, along with the hand calculator in Assignment Sheet #6.

(NOTE: Students who normally have problems with math seem to master the calculator without much problem once they figure out sequences.)

XII. Refer to *Basic Drafting, Book Two* for teaching skills related to construction of tangents and ellipses.

XIII. Show template catalog.

XIV. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
  1. TM 1--Templates--General Purpose
  2. TM 2--Templates--Threaded Fasteners
  3. TM 3--Templates--Ellipses

4. TM 4--Templates--Miscellaneous
5. TM 5--Types of Machinist Rules
6. TM 6--Uses of Rules--Measurement Transfer
7. TM 7--Uses of Rules
8. TM 8--Outside Micrometer Parts
9. TM 9--Reading a Micrometer
10. TM 10--Parts of the Inside Micrometer
11. TM 11--Inside Micrometer Set
12. TM 12--Uses of the Inside Micrometer
13. TM 13--Uses of the Inside Micrometer (Continued)
14. TM 14--Parts of a Depth Micrometer
15. TM 15--Uses of the Depth Micrometer
16. TM 16--Machinist Precision Instruments
17. TM 17--Machinist Precision Instruments (Continued)
18. TM 18--Dial and Vernier Calipers
19. TM 19--Vernier Scales
20. TM 20--Welding Measuring Instruments
21. TM 21--Mechanical Engineer Scale
22. TM 22--Machinist Steel Rules
23. TM 23--Algebraic Keyboard
24. TM 24--Hand Calculator Keyboard Sequences

D. Assignment Sheets

1. Assignment Sheet #1--Read Micrometer Settings
2. Assignment Sheet #2--Read Vernier Calipers
3. Assignment Sheet #3--Measure with Scales
4. Assignment Sheet #4--Compute Mechanical Drafting Problems Using A Hand Calculator

E. Answers to assignment sheets

F. Job sheets

  1. Job Sheet #1--Use a Micrometer

  2. Job Sheet #2--Use a Vernier Caliper

G. Test

H. Answers to test

II. References:

A. Giesecke, Frederick E., et al. *Technical Drawing.* New York 10022: Macmillan Publishing Co., Inc., 1980.

B. Wallach, Paul. *Metric Drafting.* Encino, CA: Glencoe Publishing Co., Inc., 1979.

C. Beakly, George and H.W. Leach. *The Slide Rule Electronic Hand Calculator and Metrification in Problem Solving.* New York 10022: Macmillan Publishing Co., 1975.

D. Amsbad, B.H., P.F. Ostwald, and M. L. Begeman. *Manufacturing Processes.* New York: John Wiley and Sons, 1977.

E. *Machine Shop.* Stillwater, OK: Oklahoma Trade and Industrial Education/ Oklahoma State Department of Vocational and Technical Education, 1972.

F. *Calculator Users Guide and Dictionary.* Charles J. Sippl Matrix Publishers, Inc., 1976.

TOOLS AND EQUIPMENT
UNIT II

INFORMATION SHEET

I. Terms and definitions

   A. Template--A thin, flat, plastic tool with various size openings of different shapes used to expedite the drawing of standard features

   B. Precision instruments--Instruments used by machinists to measure and gage products

   (NOTE: Gage is often spelled gauge.)

   C. Transfer artwork--Preprinted letters, symbols, and shading that can be rubbed on or cut out for drawings to save drafting time

   D. Scale--Instrument used as a standard of reference when drawing an object to a proportional size

   E. Hand calculator--Calculating device to solve mathematical problems

   F. Logic--Arrangement of a sequence of operations

   G. Datums--Points, lines, or other geometric shapes assumed to be exact from which the location or geometric form of features of a part may be estimated

II. Mechanical templates (Transparencies 1-4)

   A. General purpose

      1. Circles
      2. Squares
      3. Arrows
      4. Hexagons
      5. Octagons
      6. Triangles

   B. Welding

   C. Threaded fasteners

      1. Nuts
      2. Bolts
      3. Screws
      4. Threads

INFORMATION SHEET

D. Springs

E. Three dimensional

1. Projection ellipses
2. Isometric ellipses
3. Isometric hexagon bolt heads and nuts
4. Projection hexagon bolt heads and nuts

III. Machinist precision measuring instruments and functions (Transparencies 5-19)

(NOTE: Machinist precision measuring instruments are expensive and should be handled with care and stored properly.)

A. Rules--Distance measurements

B. Outside micrometer--Accurate outside measurements

C. Inside micrometer--Accurate inside measurements

D. Depth micrometer--Depth of slots of holes from datum surfaces

E. Caliper--Approximate internal and external measurements

F. Vernier caliper--Both inside and outside measurements

G. Dial caliper--Continuous reading and dial test indicators for gaging

(NOTE: The dial on this caliper may be metric.)

H. Height transfer gage for surfaces--Accurate parallel surface measurements

I. Sine bar--Accurate angle measurements

J. Dial indicator gage--Alignment, eccentricity, or deviations on surfaces

K. Snap gage--Plain external dimensions for "go" or "no go" gaging

L. Plug gage--Internal dimensions of holes for "go" or "no go" gaging

M. Divider--Dimension transfers and circle scribes

N. Optical comparator--Comparison of finished part to a master or lines on a screen

(NOTE: These instruments are very accurate in measurement, location of datums, and gaging of surfaces and holes. These instruments may be calibrated in decimals of an inch or metric.)

INFORMATION SHEET

IV. Types of welding measuring instruments (Transparency 20)

  A. Combination square

  B. Steel rule

  C. Steel square

  D. Tapes

  E. Outside caliper

  F. Inside caliper

V. Types of scales used in mechanical drafting (Transparencies 21 and 22)

  A. Mechanical engineer scale

  B. Machinist steel rule

  C. Metric scale

VI. Primary metric unit of measurement used in mechanical drafting--Millimeter

(NOTE: The meter and kilometer are secondary scales. The centimeter and decimeter are rarely used.)

VII. Scales used in mechanical drafting

  A. Mechanical engineer scale (Transparency 21)

  (NOTE: Review "Mechanical Engineer's Scale Usage," Unit VII, of *Basic Drafting, Book One* for use of these scales.) .

    1. Fractions (scale ratio)--Open divided

      a. 1"=1"--Full size

      b. 1/2"=1"--Half size

      c. 1/4"=1"--Quarter size

      d. 1/8"=1"--One-eighth size

    2. Decimal--Full divided

      a. 10 parts per inch--Each division equals .1"

      b. 50 parts per inch--Each division equals .02"

INFORMATION SHEET

B. Machinist steel rule (common) (Transparency 22)

1. Fractions--English
    a. 32 parts per inch--Each division equals 1/32"
    b. 64 parts per inch--Each division equals 1/64"
2. Decimal--English
    a. 10 parts per inch--Each division equals .1"
    b. 50 parts per inch--Each division equals .02"
3. Metric--IS

    (NOTE: Review "Metric Scale Usage," Unit VIII, of *Basic Drafting, Book One* for use of these scales.)

    a. Millimeters (mm)--Each division equals 1mm
    b. 1/2 millimeters--Each division equals .5mm

    (NOTE: Machinist steel rules may be found in various combinations of fractions, decimals, and metrics in the common scales above or other scales.)

C. Metric scale

1. 1:1
2. 1:2
3. 1:3
4. 1:5
5. 1:10

VIII. Hand calculator functions (Transparency 23)

A. Primary

1. Add
2. Subtract
3. Multiply
4. Divide

INFORMATION SHEET

B. Secondary

   1. Reciprocal
   2. Square
   3. Square root
   4. Logarithm
   5. Trigonometric
   6. Storage (memory)
   7. Antilogarithm
   8. Angular mode (radians-degrees)
   9. Hyperbolic

IX. Types of keyboard sequences used in hand calculators (Transparency 24)

A. Lukasciewicz

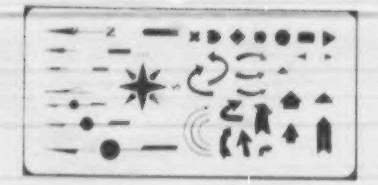
   1. Is referred to as "reverse Polish"
   2. Has operational stack
   3. Usually takes fewer steps

B. Algebraic

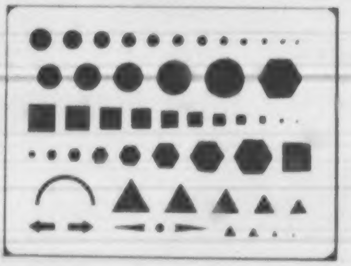
   1. Is easy to master
   2. Sometimes takes more steps

Templates

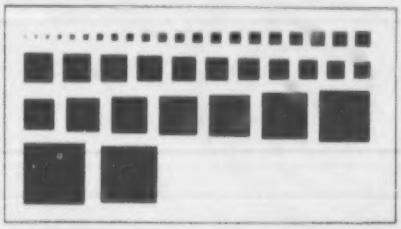
General Purpose



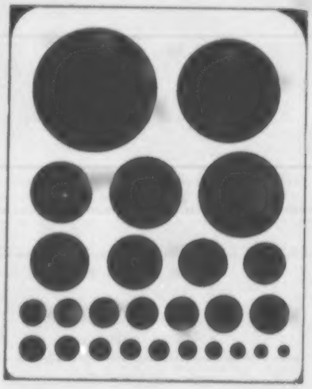
Professional Arrow



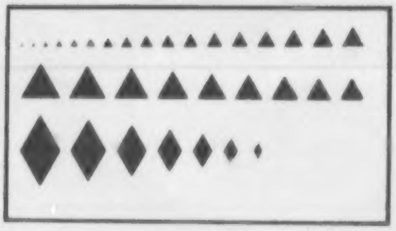
General Purpose



Square Template



Circle Master



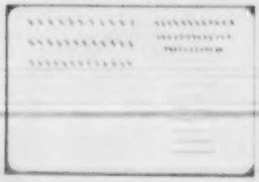
Triangles/Diamonds

Dimensioning Arrows

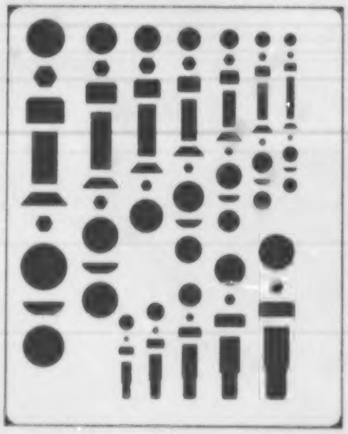
Courtesy of
Chartpak-Pickett

Templates

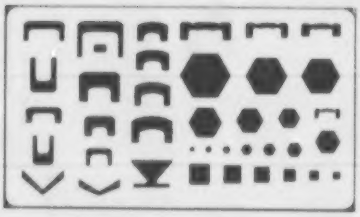
Threaded Fasteners



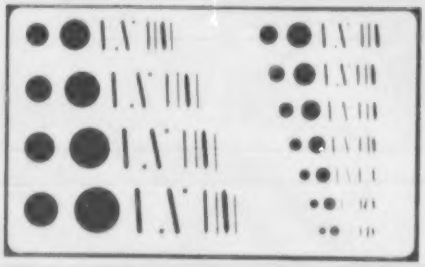
Screw Threads



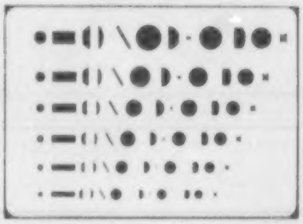
Hexagon Socket Screws



Nut, Bolt, and Screw Template



Springs and Screw Threads



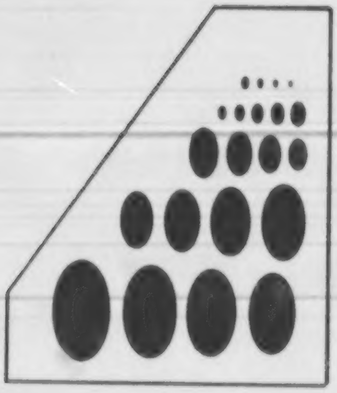
Small Machine Screw Template

Standard Screw Heads

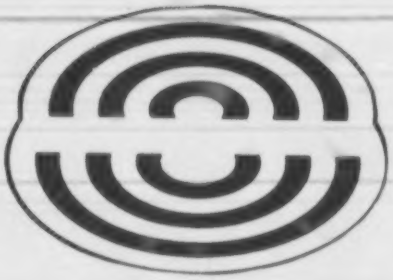
Courtesy of
Chartpak-Pickett

Templates

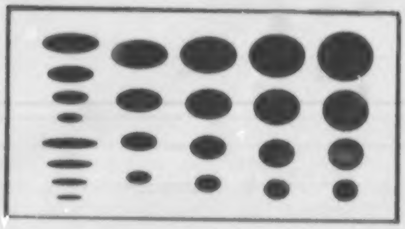
Ellipses



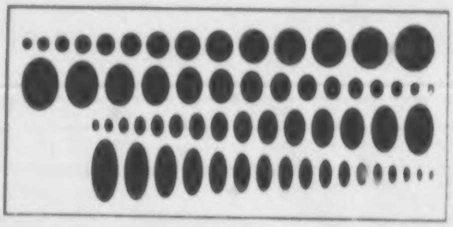
Isometric Ellipse



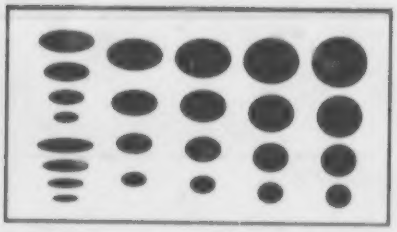
Large Isometric Ellipse



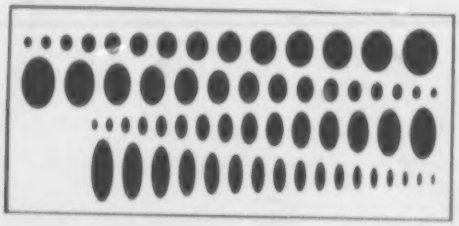
Master Ellipse



Master Ellipse



Master Ellipse

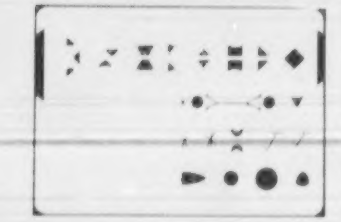


Master Ellipse

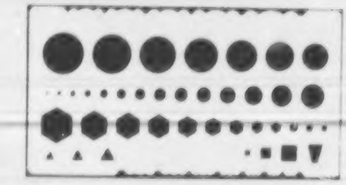
Courtesy of
Chartpak-Pickett

Templates

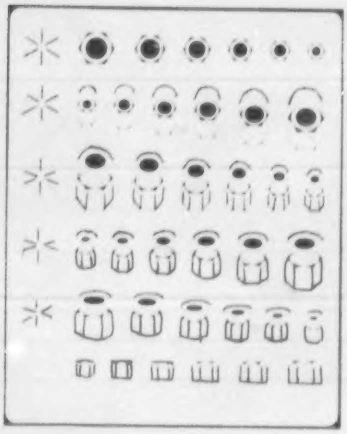
Miscellaneous



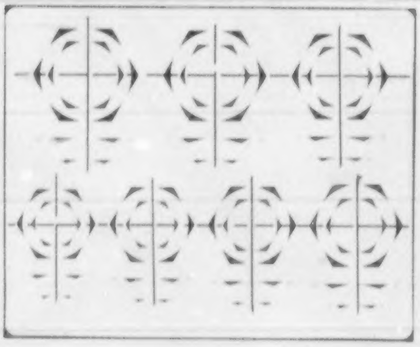
Welding Symbols



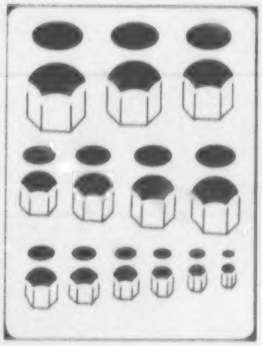
Tool Planner



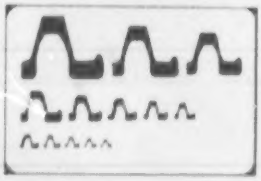
Hexagon Nuts



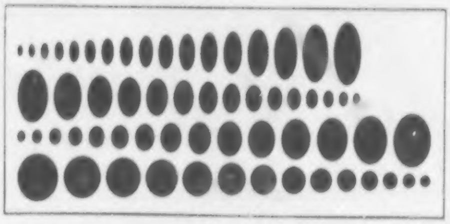
Large Hexagon Bolts and Nuts



Isometric Hexagon
Heads and Nuts



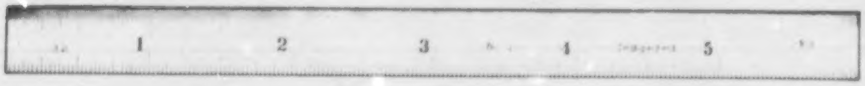
Involute Rack and Spur Gear



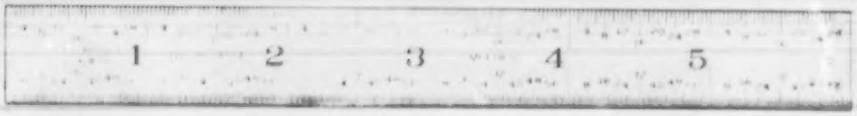
Isometric Springs

Courtesy of
Chartpak-Pickett

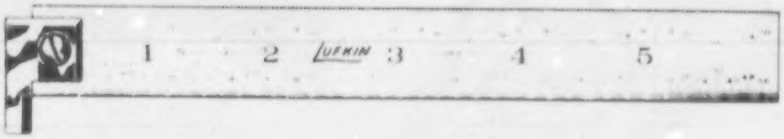
Types of Machinist Rules



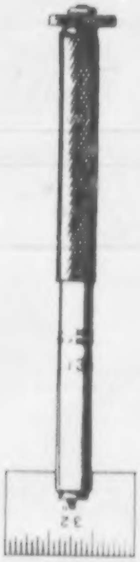
Narrow Flexible Rule



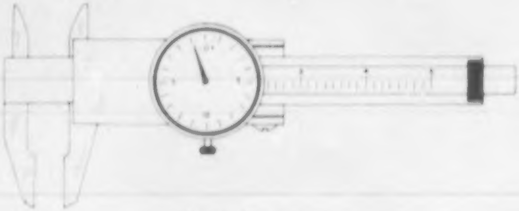
Steel Rule


1
2
LUFKIN
3
4
5

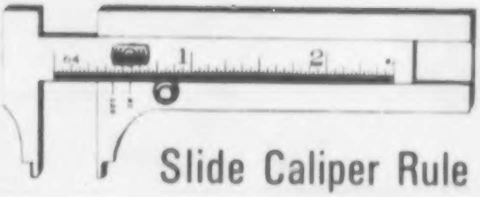
Hook Rule



Short Rule with Holder



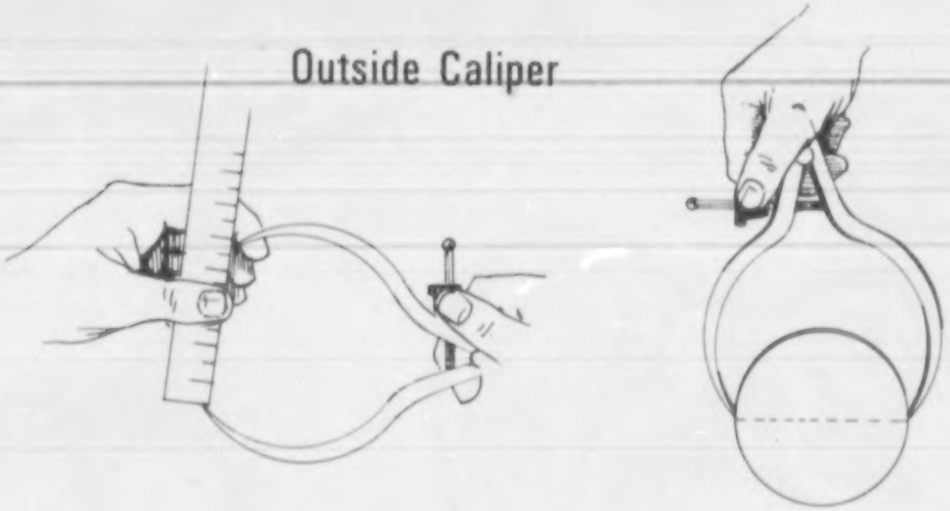
Dial Caliper



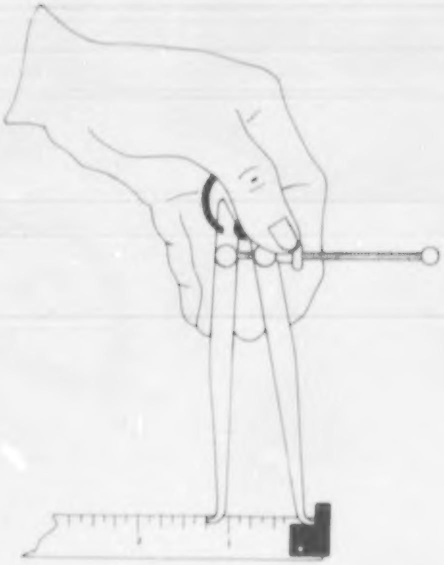
Slide Caliper Rule

Uses of Rules

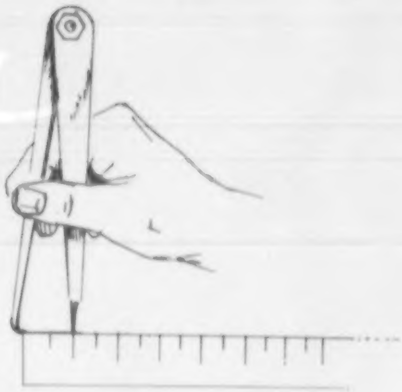
MEASUREMENT TRANSFER



Outside Caliper

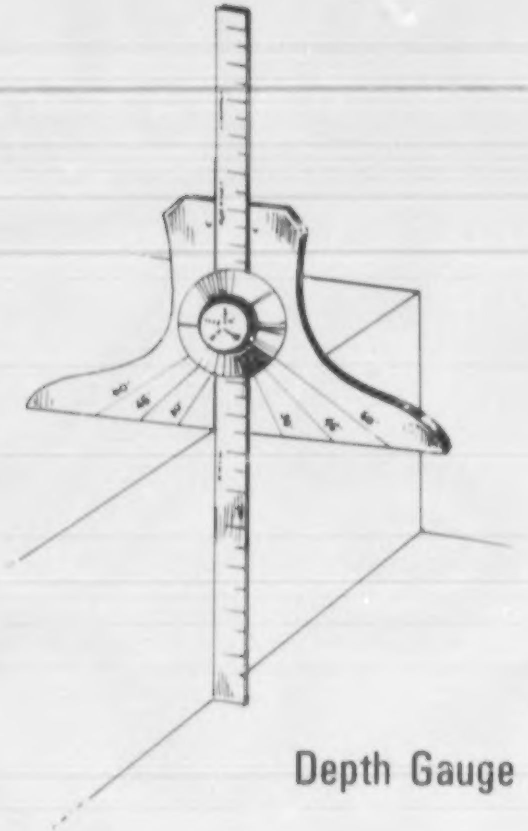


Inside Caliper

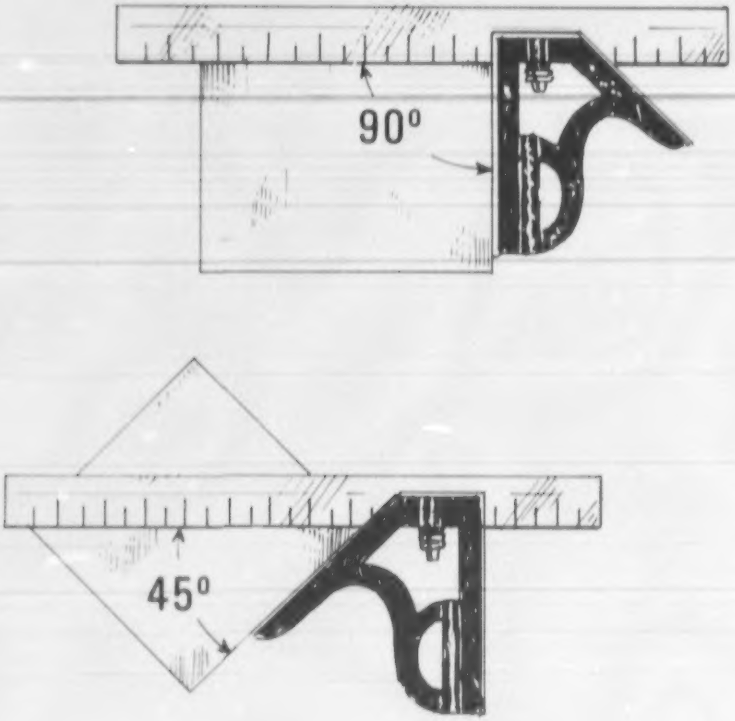


Hermaphrodite Caliper

Uses of Rules

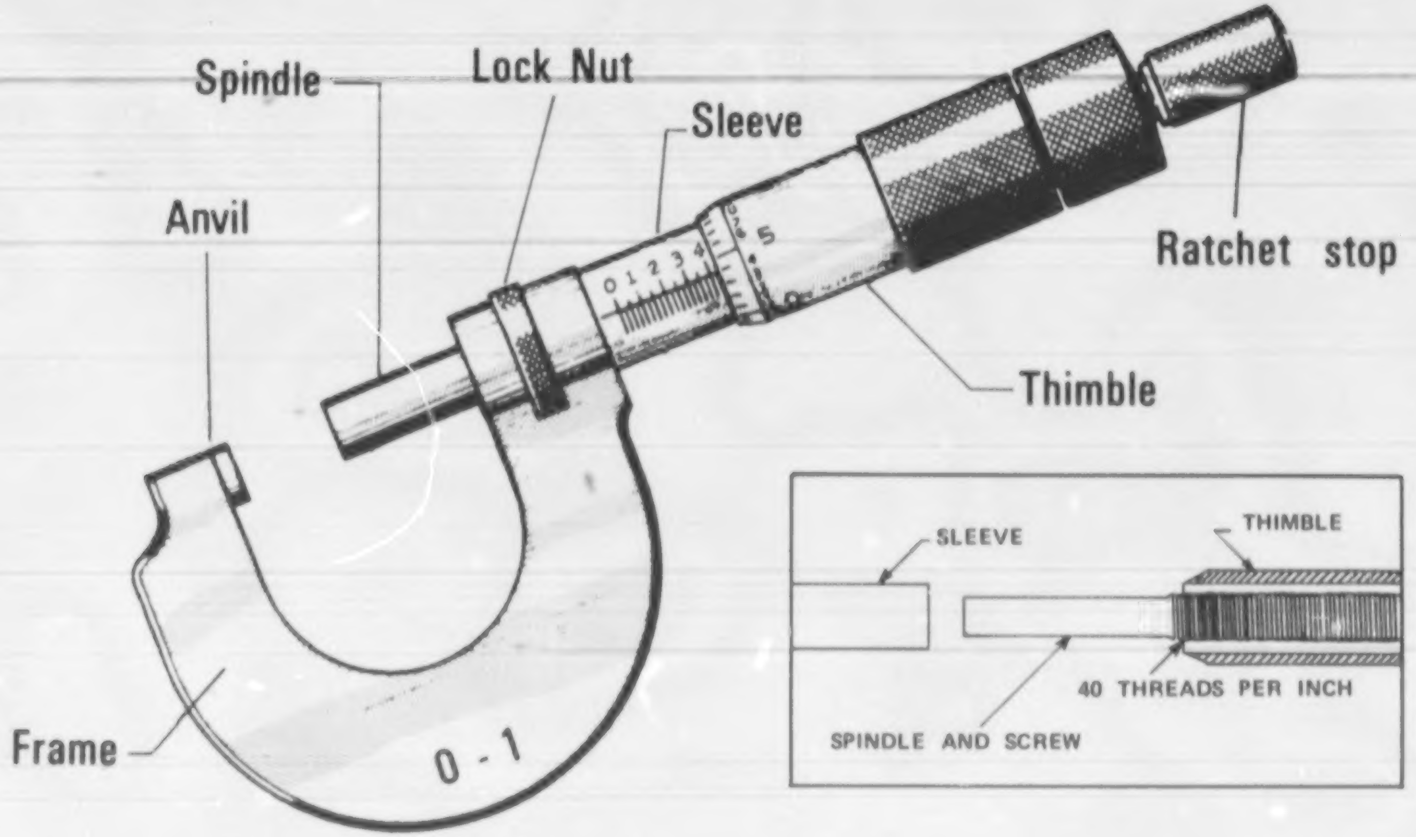


Depth Gauge



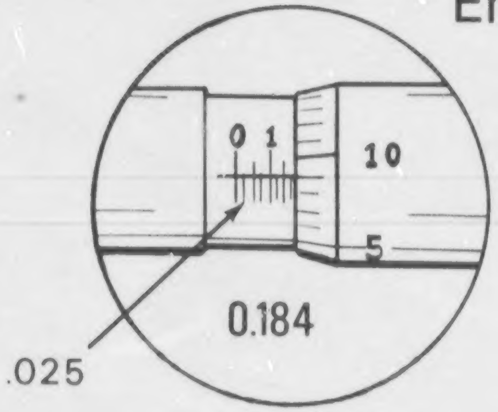
Combination Square

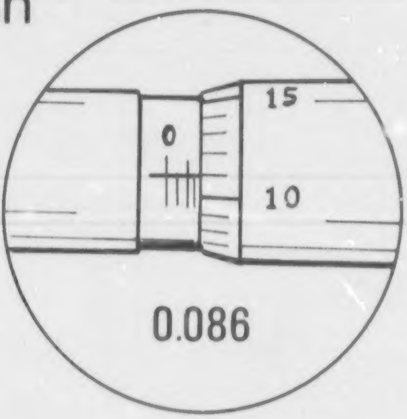
Outside Micrometer Parts


Spindle
Lock Nut
Sleeve
Anvil
Ratchet stop
Thimble
Frame
0 - 1
SLEEVE
THIMBLE
40 THREADS PER INCH
SPINDLE AND SCREW

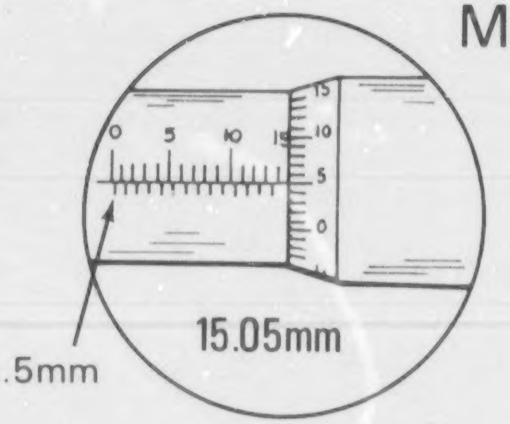
Reading a Micrometer

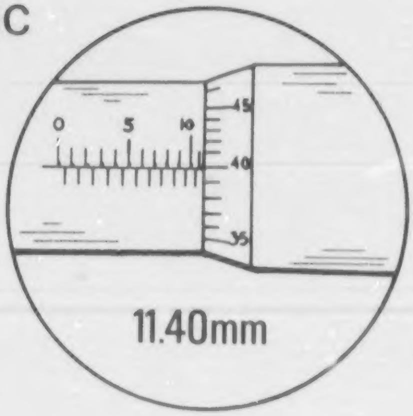
English


0
1
10
5
0.184
.025

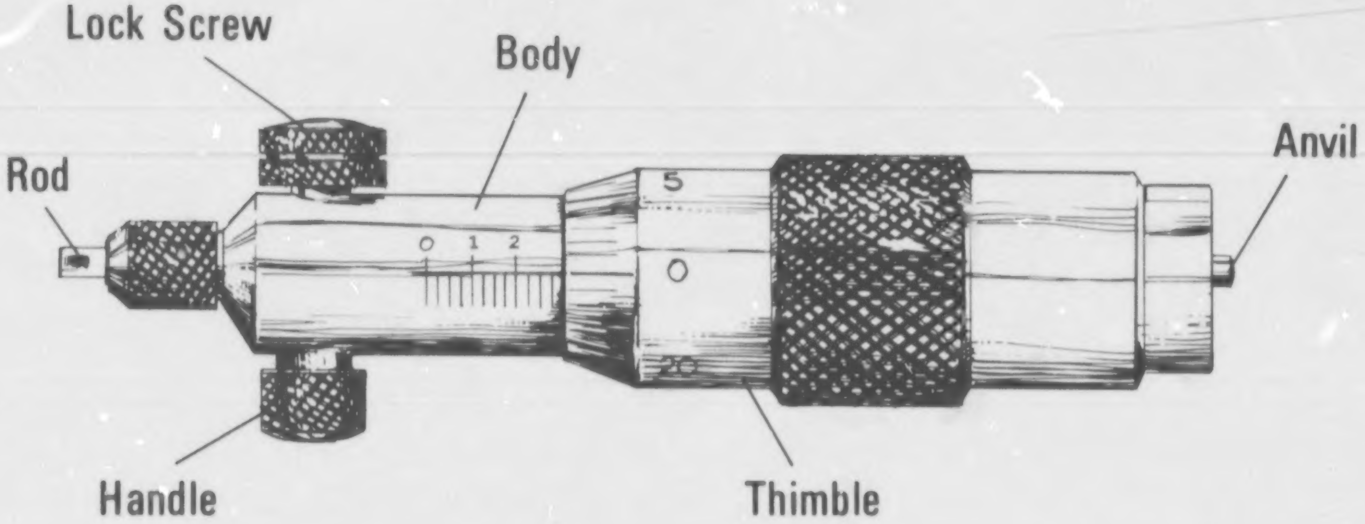


Metric


0
5
10
15
15
10
5
0
15.05mm
.5mm

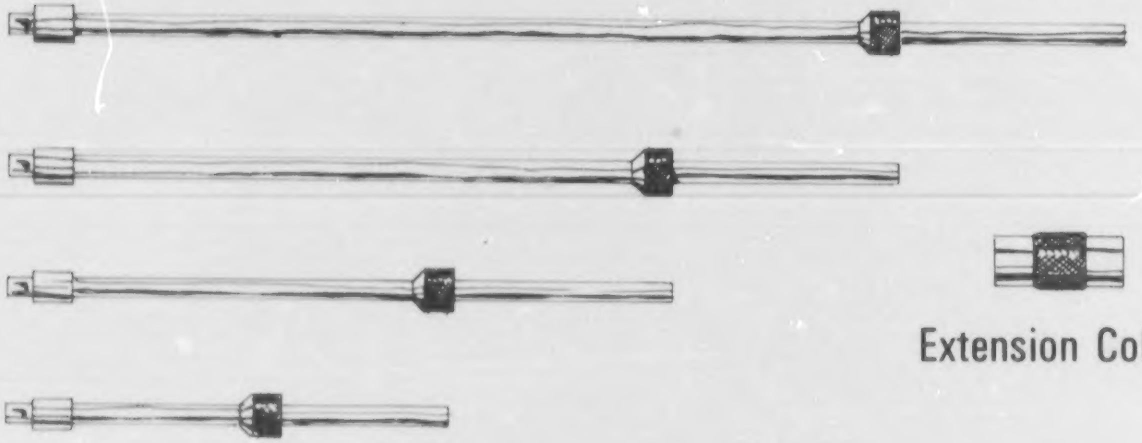

0
5
10
45
40
35
11.40mm

Parts of the Inside Micrometer

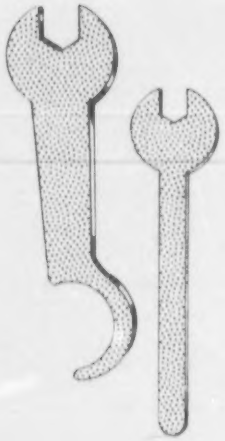

Lock Screw
Body
Rod
Anvil
5
0 1 2
0
20
Handle
Thimble

Inside Micrometer Set

Extension Rods

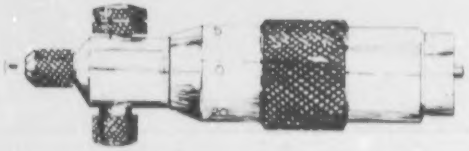


Extension Collar

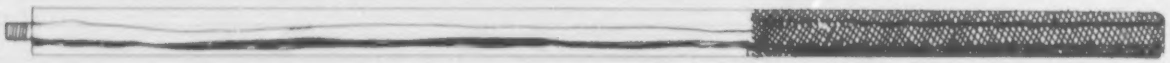


Wrenches

Height Gauge Base

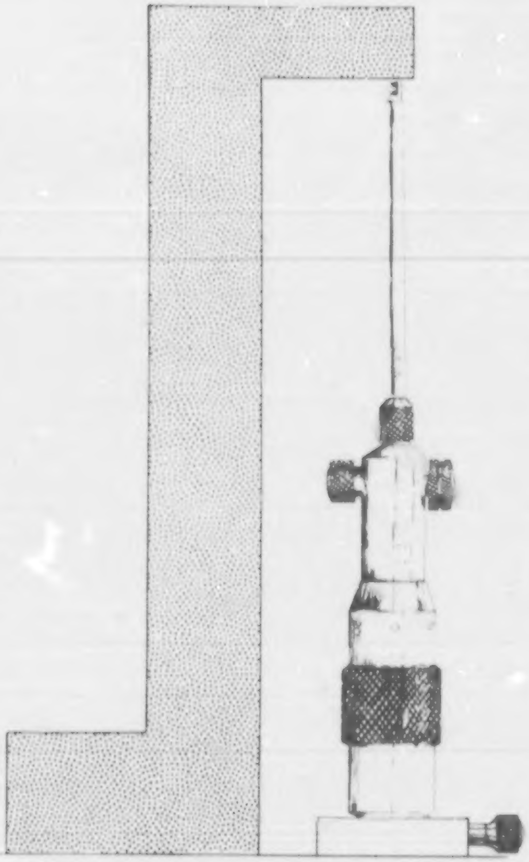


Base Unit

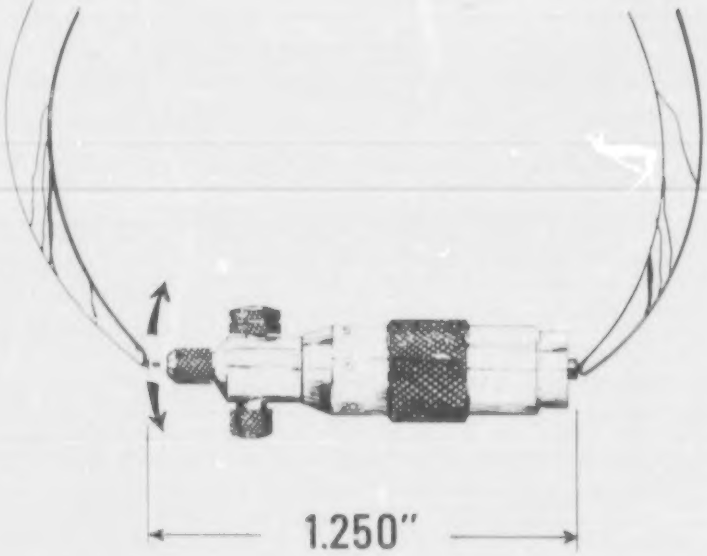


Extension Handle

Uses of the Inside Micrometer

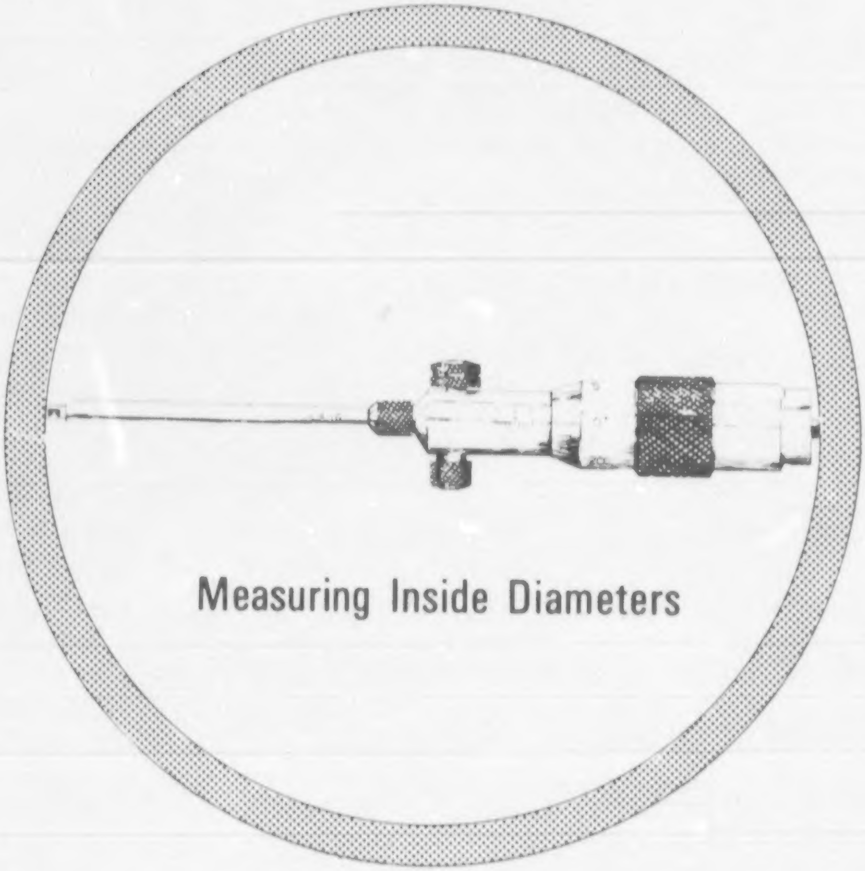


Height Gauge



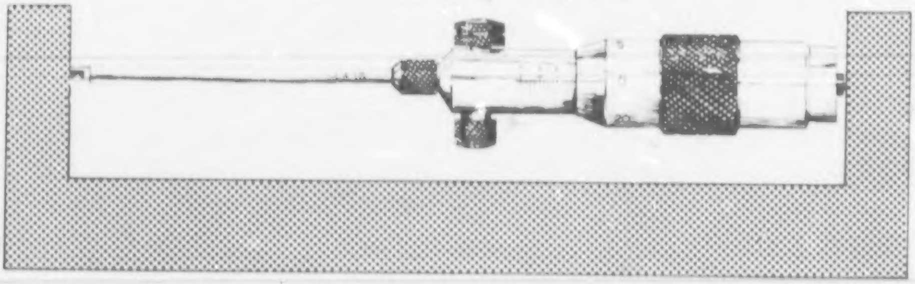
Measurement Transfer

Uses of the Inside Micrometer
(Continued)

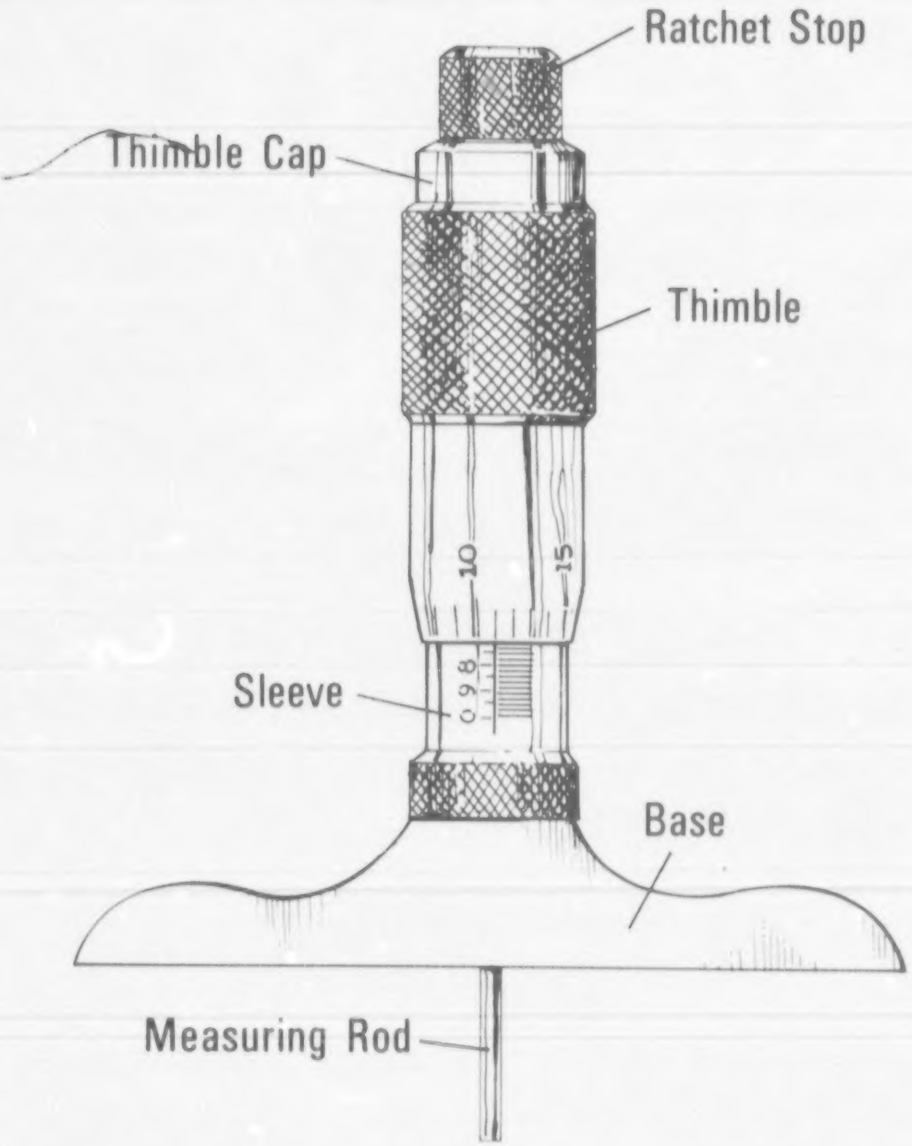


Measuring Inside Diameters

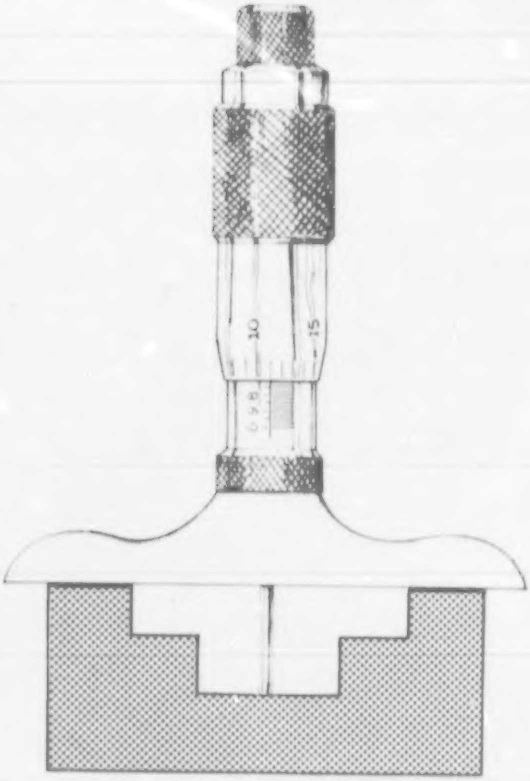
Measuring Widths



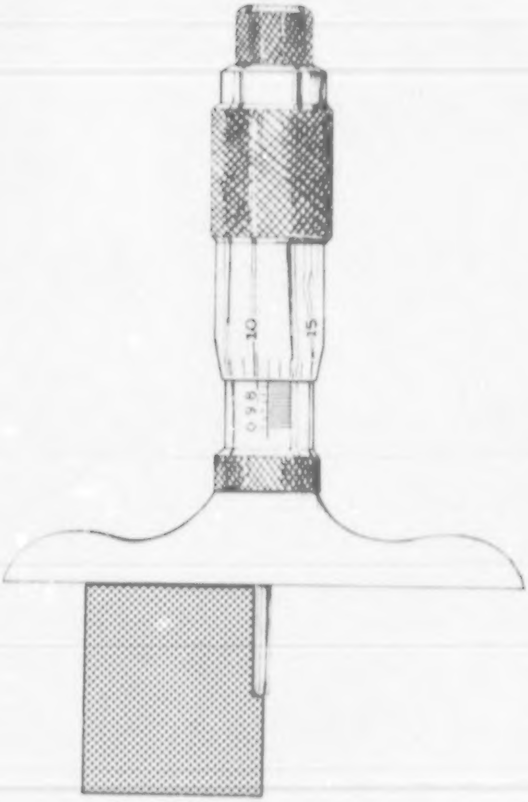
Parts of a Depth Micrometer


Ratchet Stop
Thimble Cap
Thimble
10
15
0 9 8
Sleeve
Base
Measuring Rod

Uses of the Depth Micrometer

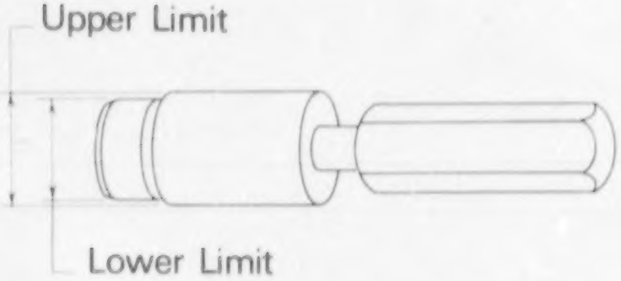


Measuring Depth of Milled Slot



Measuring Shallow Recess

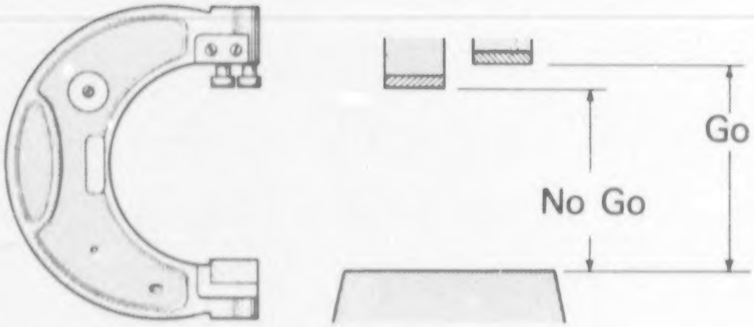
Machinist Precision Instruments

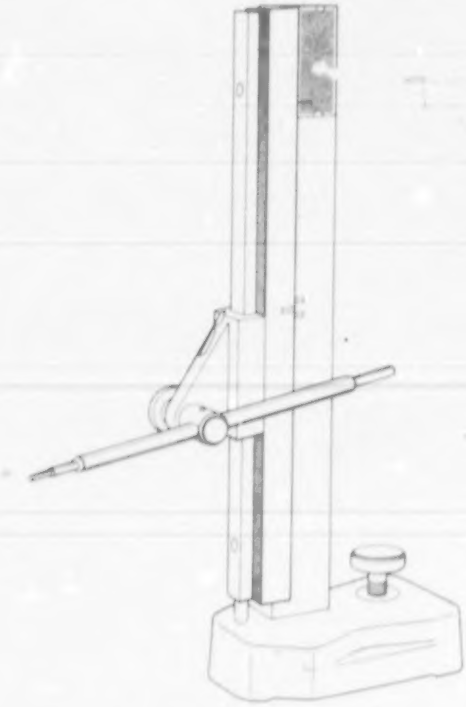


Plug Gage for

Checking a Hole Size

Adjustable Limit
Snap Gage
Set for Inspecting
a Dimension



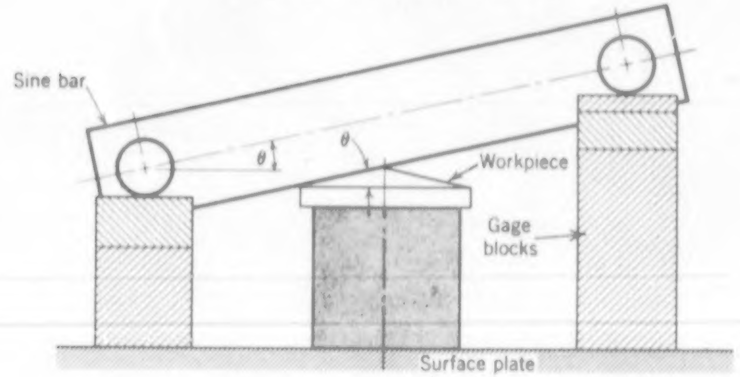


Height Transfer
Gage for Surfaces

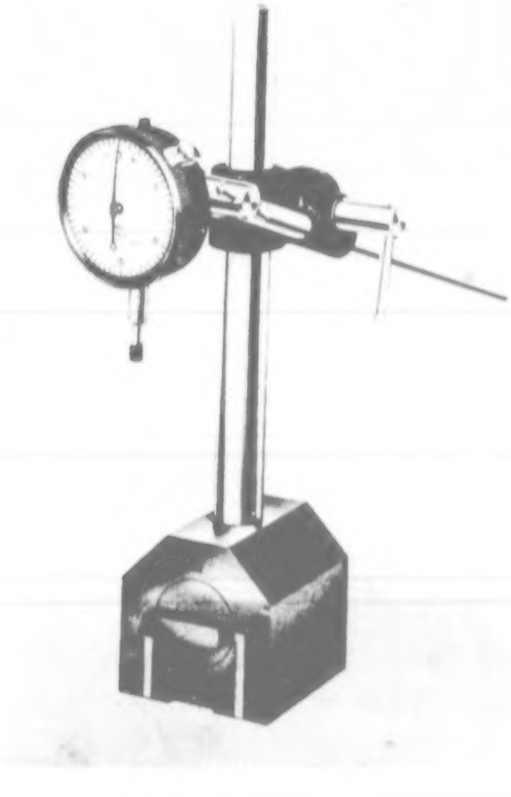
From *Manufacturing Processes* by B.H. Amsbad, P.F. Ostwald, and M.L. Begeman. ©1977. Reprinted by permission of John Wiley and Sons, Inc.

Machinist Precision Instruments

(Continued)


Sine bar
θ
θ
Workpiece
Gage blocks
Surface plate

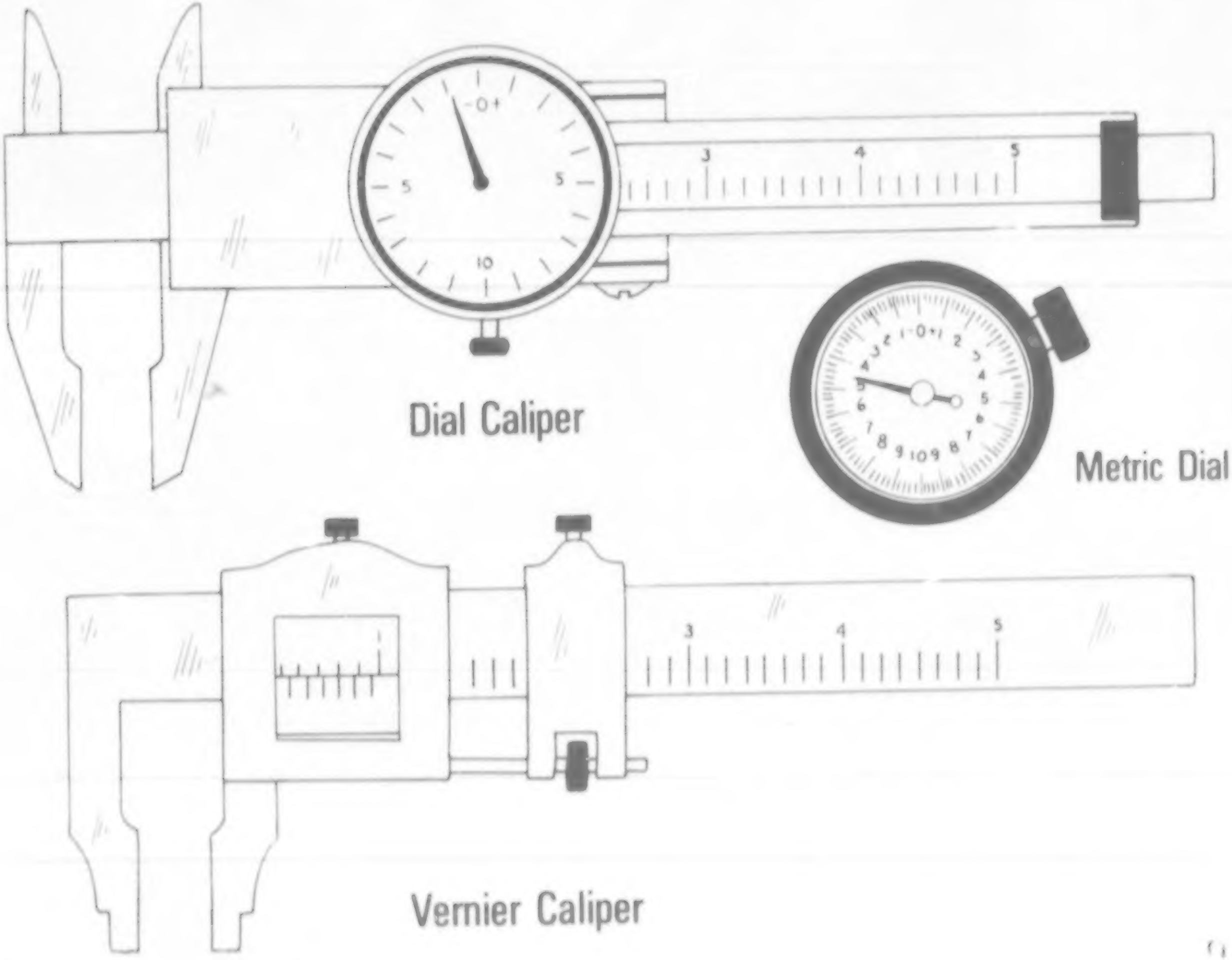
Sine Bar Setup on Gage Blocks for Measuring an Angle on a Workpiece



Dial Indicating Gage with Permanent Magnet Base

From *Manufacturing Processes* by B.H. Amsbad, P.F. Ostwald, and M.L. Begeman. ©1977. Reprinted by permission of John Wiley and Sons, Inc.

Dial and Vernier Calipers



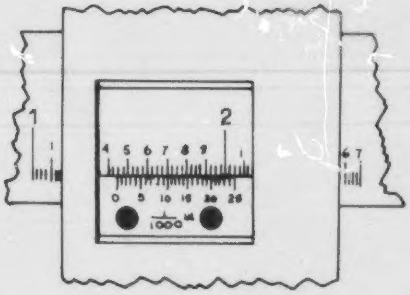
Dial Caliper

Metric Dial

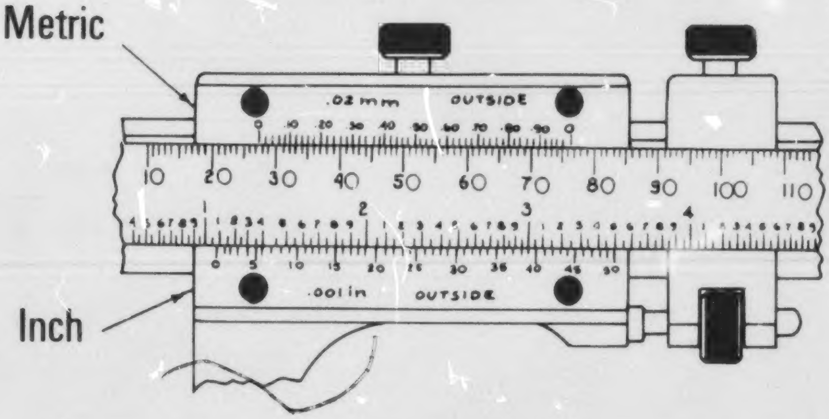
Vernier Caliper

-0+
5
5
10
3
4
5
-0+
1
2
3
4
5
6
7
8
9
10
9
8
7
6
5
4
3
2
1
3
4
5

Vernier Scales

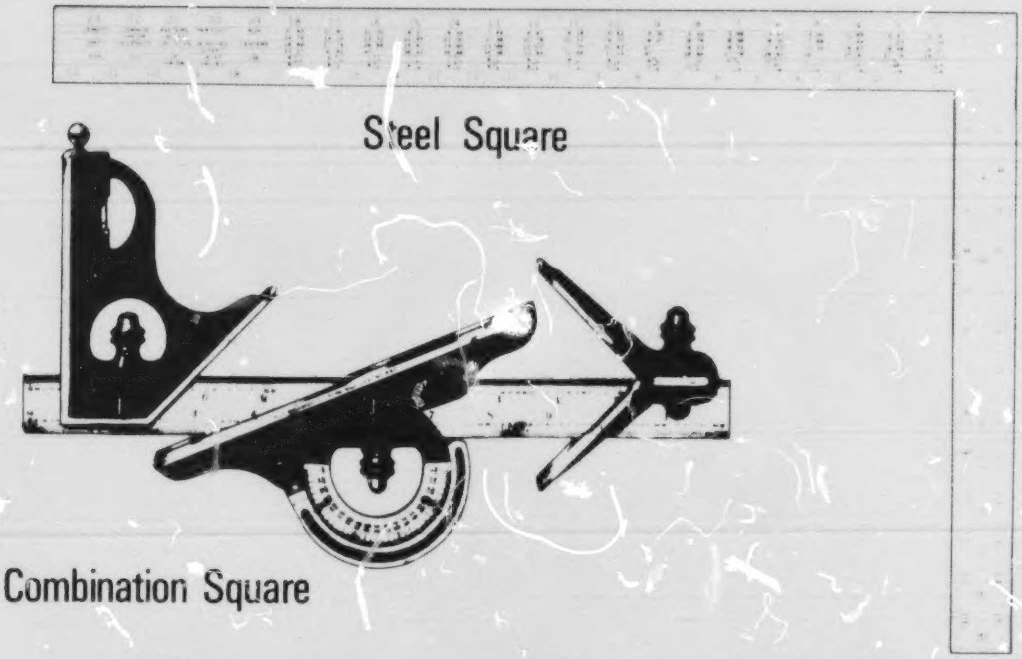

1
2
4 5 6 7 8 9 1
0 5 10 15 20 25
1/1000 in
6 7

25 Division
Inch Caliper


Metric
.02 mm
OUTSIDE
0 .10 .20 .30 .40 .50 .60 .70 .80 .90 0
10 20 30 40 50 60 70 80 90 100 110
1 2 3 4
0 5 10 15 20 25 30 35 40 45 50
.001 in
OUTSIDE
Inch

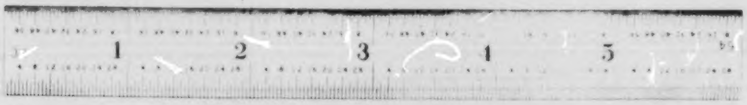
50 Division Inch
and Metric Caliper

Welding Measuring Instruments

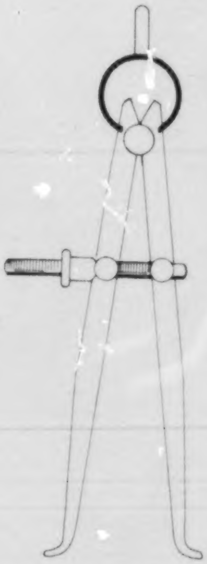


Steel Square

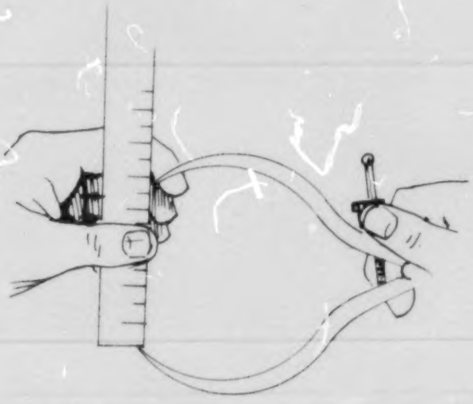
Combination Square



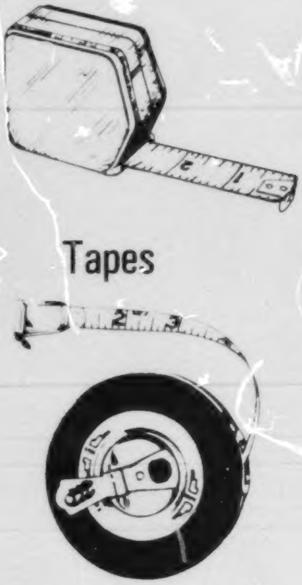
Steel Rule



Inside Caliper

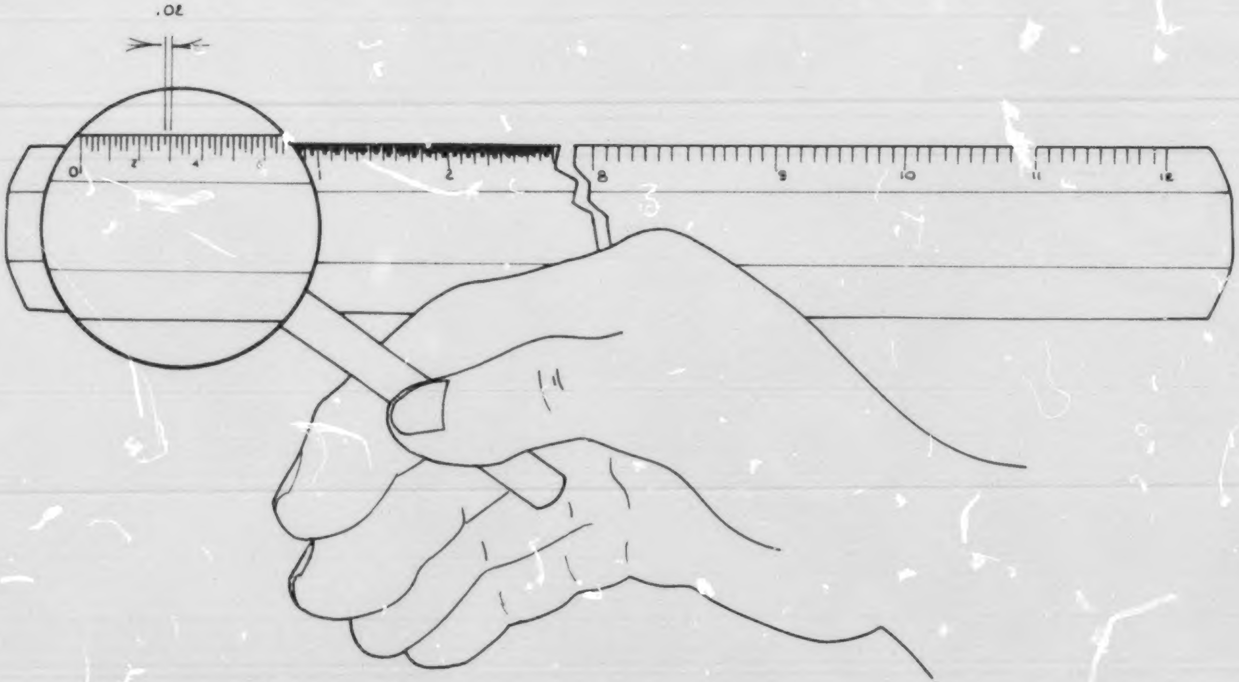


Outside Caliper

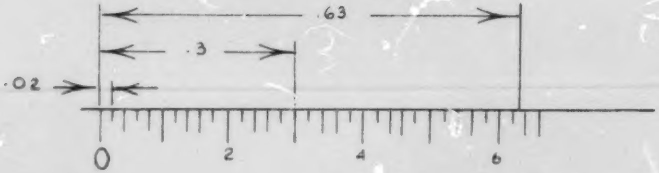


Tapes

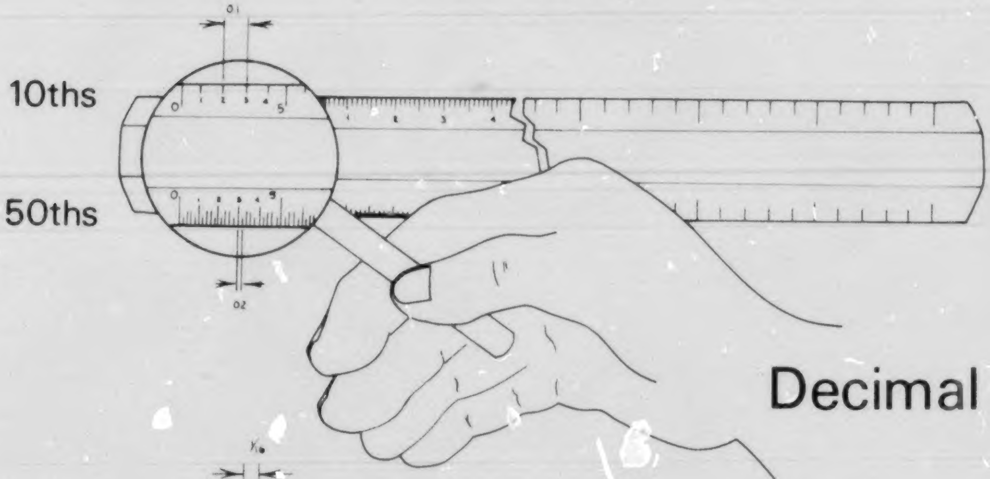
Mechanical Engineer Scale


.02
0
2
4
6
1
2
8
9
10
11
12

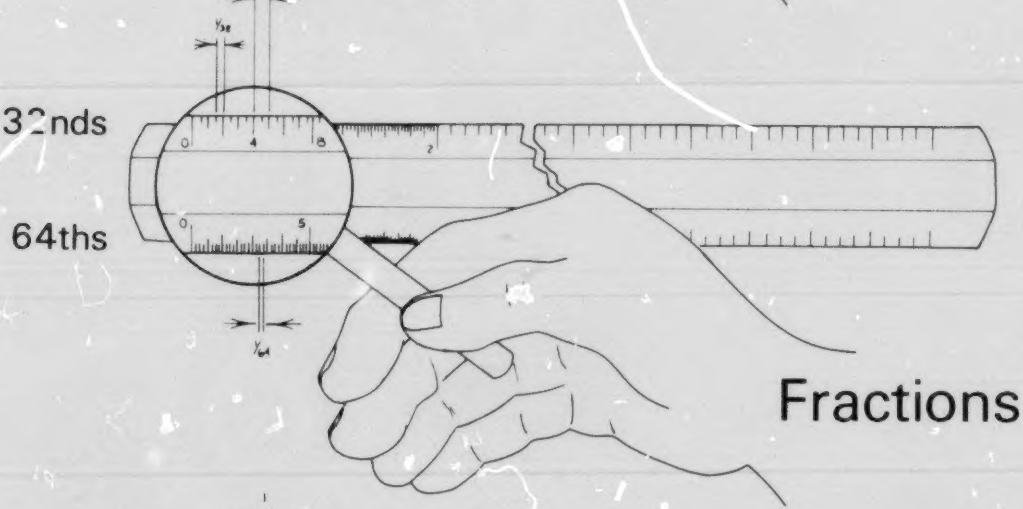
Decimal



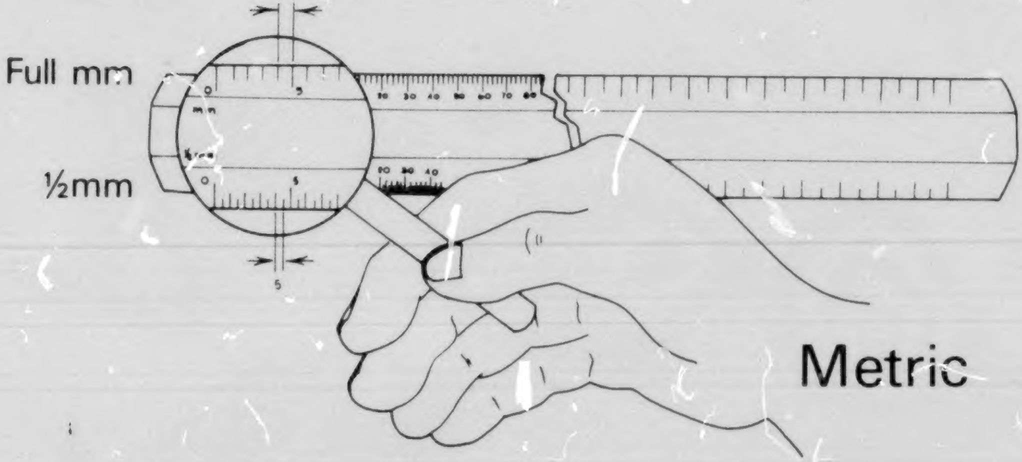
Machinist Steel Rules


.01
10ths
50ths
.02

Decimal

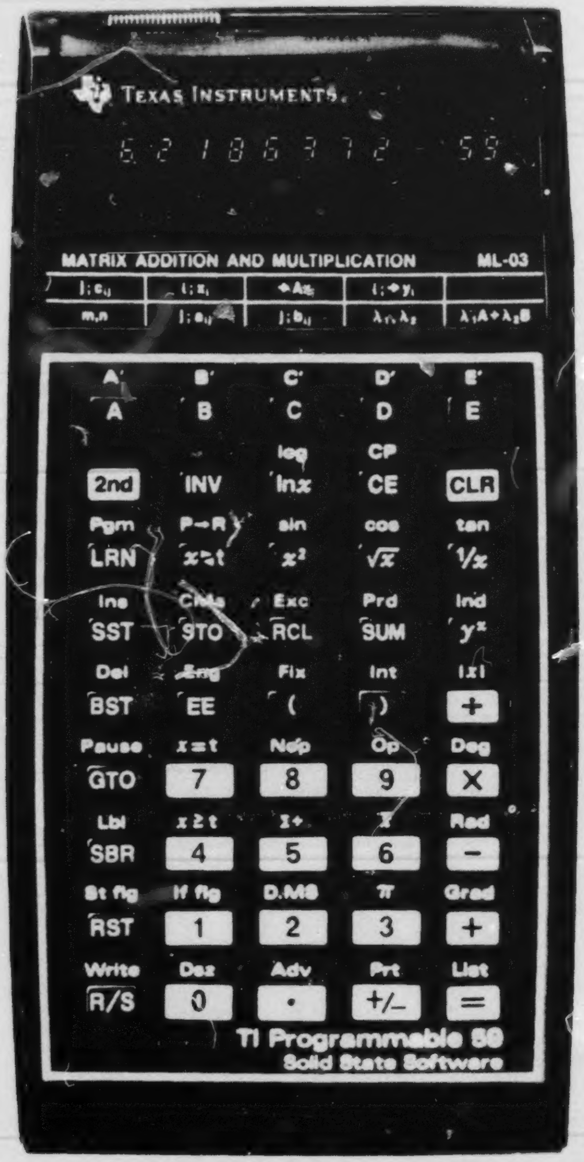

1/16
1/32
32nds
64ths
1/64

Fractions


1
Full mm
½mm
.5

Metric

Algebraic Keyboard


TEXAS INSTRUMENTS
MATRIX ADDITION AND MULTIPLICATION
ML-03
A' B' C' D' E'
A B C D E
log CP
2nd INV lnx CE CLR
Pgm P→R sin cos tan
LRN x⇌t x² √x 1/x
Ins CMs Exc Prd Ind
SST STO RCL SUM yˣ
Del Eng Fix Int |x|
BST EE ( ) ÷
Pause x=t Nop Op Deg
GTO 7 8 9 ×
Lbl x≥t Σ+ x̄ Rad
SBR 4 5 6 −
St flg If flg D.MS π Grad
RST 1 2 3 +
Write Dsz Adv Prt List
R/S 0 . +/− =
TI Programmable 58
Solid State Software

Courtesy of Texas Instruments, Inc.

Hand Calculator Keyboard Sequences

Problem	Entries Needed	
	Lukasciewicz	Algebraic
(3×4) + (7×8)=?	3 ↑ 4 × 7 ↑ 8 × +	3 × 4 + 7 × 8 =
(3+4) × (7+8)=?	3 ↑ 4 + 7 ↑ 8 + ×	3 + 4 = STO 7 + 8 = × RCL =
(3+4) ÷ (7+8)=?	3 ↑ 4 + 7 ↑ 8 + ÷	3 + 4 = STO 7 + 8 = ÷ RCL $x \gtrless y$ =

TOOLS AND EQUIPMENT
UNIT II

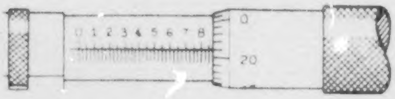
ASSIGNMENT SHEET #1--READ MICROMETER SETTINGS

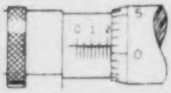
(NOTE: Students should complete Job Sheet #1 before attempting this assignment.)

Directions: Read the micrometer settings below, and place your answers in the blanks provided at the right of the page.

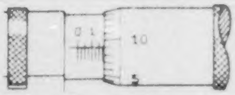
Problems:

A. Inch

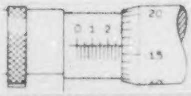

0 1 2 3 4 5 6 7 8
0
20
1



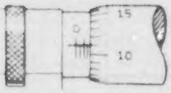
2



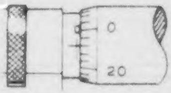
3



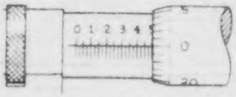
4



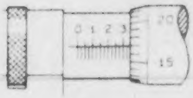
5



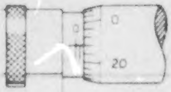
6



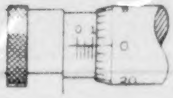
7



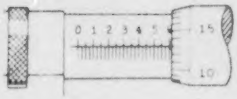
8

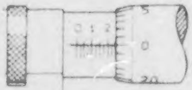


9

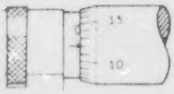


10


0 1 2 3 4 5
15
10
11



12



13

Answers

A.

1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.

ASSIGNMENT SHEET #1

B. Metric

B.

1. ______________________

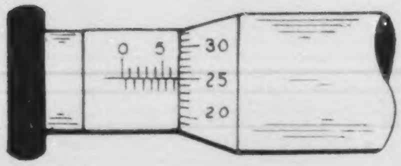
2. ______________________

3. ______________________

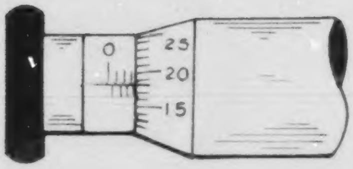
4. ______________________

5. ______________________

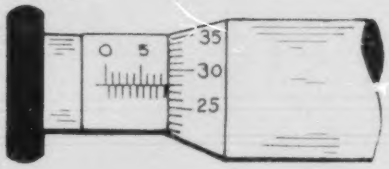
6. ______________________



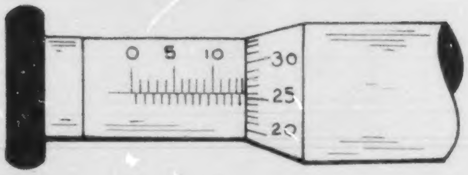
1



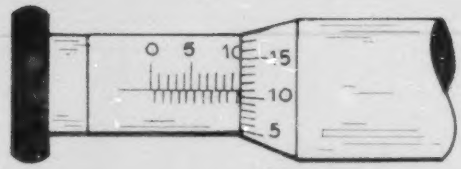
2



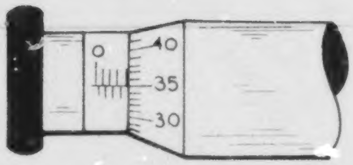
3


0
5
10
30
25
20

4



5



6

TOOLS AND EQUIPMENT
UNIT II

ASSIGNMENT SHEET #2--READ VERNIER CALIPERS

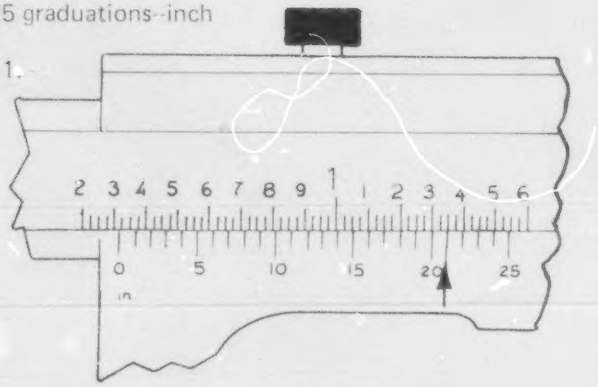
(NOTE: Students should complete Job Sheet #2 before attempting this assignment.)

Directions: Read the vernier caliper settings below, and place your answers in the blanks provided at the right of the page.

Problems: Answers

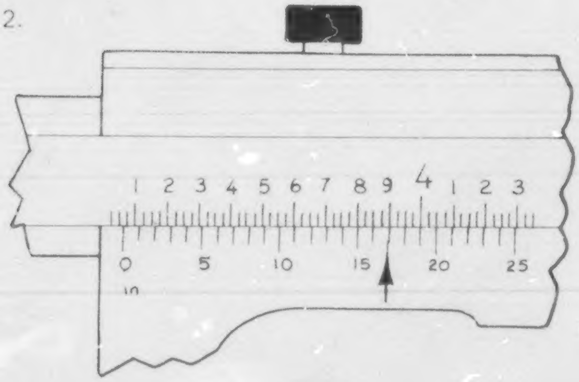
A. 25 graduations--inch

1.


2 3 4 5 6 7 8 9 1 1 2 3 4 5 6
0 5 10 15 20 25
in

1. ____________________

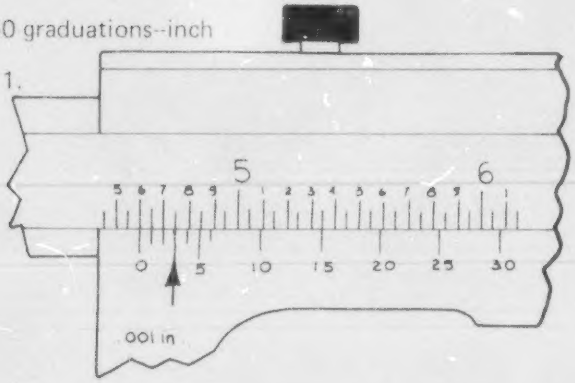
2.


1 2 3 4 5 6 7 8 9 4 1 2 3
0 5 10 15 20 25
in

2. ____________________

B. 50 graduations--inch

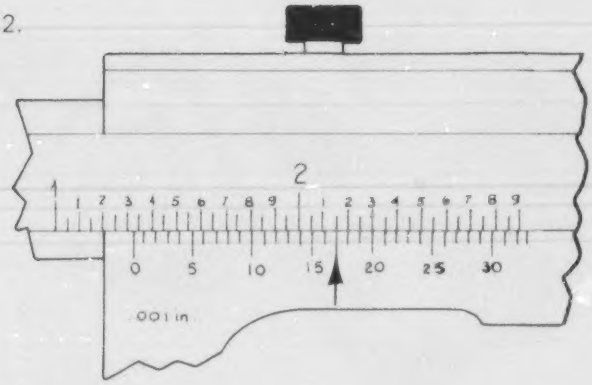
1.


5 6
5 6 7 8 9 1 2 3 4 5 6 7 8 9 1
0 5 10 15 20 25 30
.001 in

1. ____________________

ASSIGNMENT SHEET #2

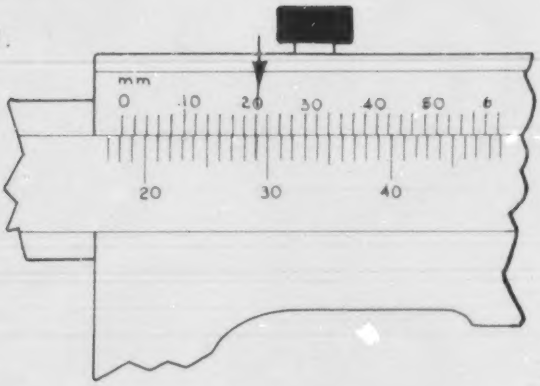
2.


2
1 2 3 4 5 6 7 8 9
1 2 3 4 5 6 7 8 9
0 5 10 15 20 25 30
.001 in

2. ____________________

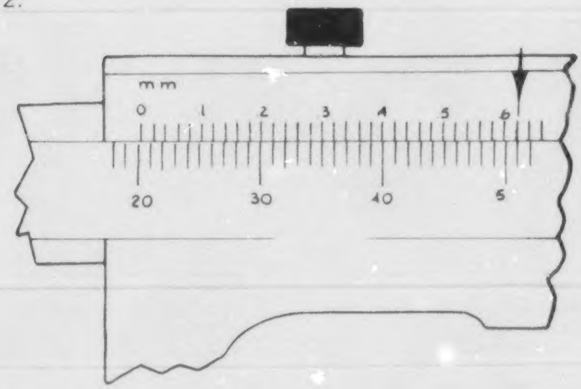
C. Metric

1.


mm
0 10 20 30 40 50 6
20 30 40

1. ____________________

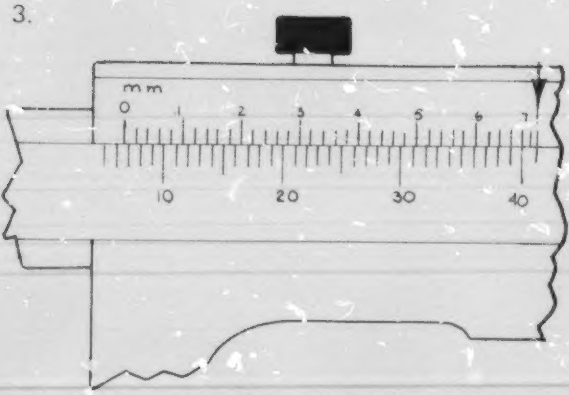
2.


mm
0 1 2 3 4 5 6
20 30 40 5

2. ____________________

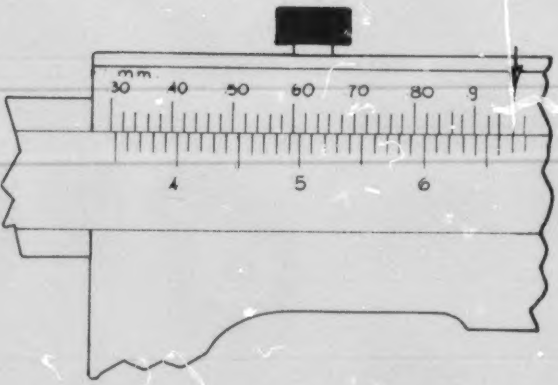
ASSIGNMENT SHEET #2

3.


mm
0
1
2
3
4
5
6
7
10
20
30
40

3. ______________________

4.


mm.
30
40
50
60
70
80
9
4
5
6

4. ______________________

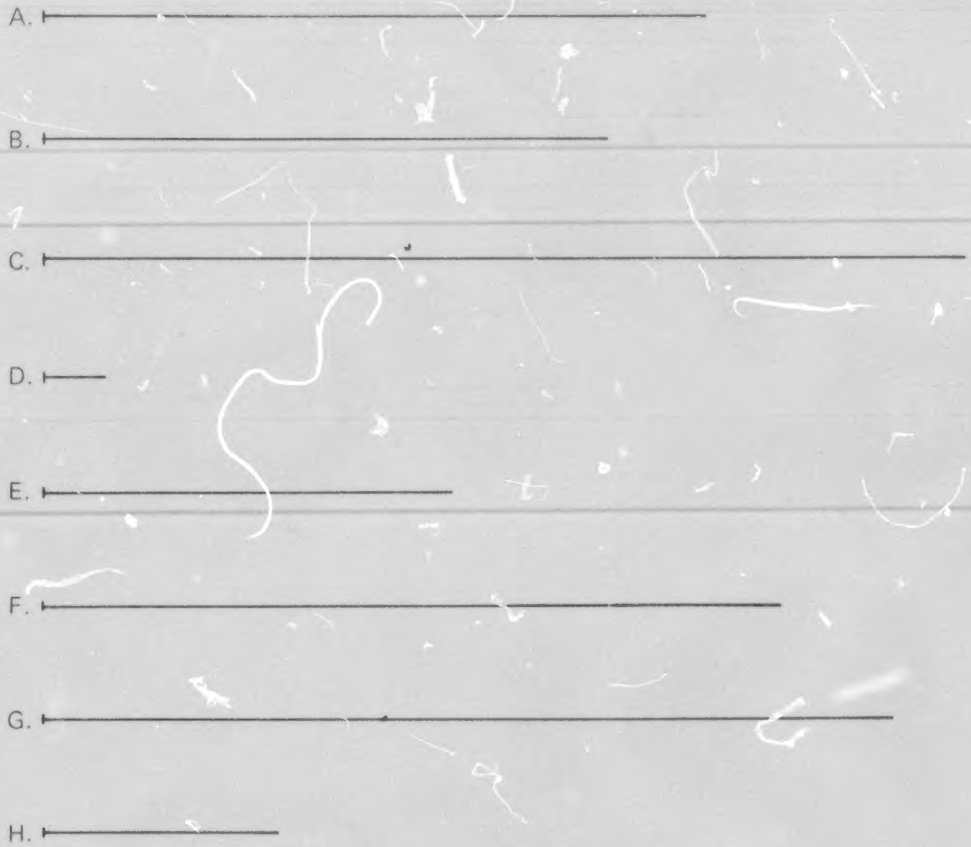
TOOLS AND EQUIPMENT
UNIT II

ASSIGNMENT SHEET #3--MEASURE WITH SCALES

Directions: Measure the lines A through H using each of the scales indicated at the top of each column in the following tables. Place the scale readings in the appropriate spaces in the tables.

Example: Measure line "A" with a mechanical engineer scale with inches reading in 50ths. A reading of 3.89" is obtained. This dimension is placed under the decimal column of the mechanical engineer scale table.

Problems:



ASSIGNMENT SHEET #3

	MECHANICAL ENGINEER SCALE			METRIC SCALE (mm) (One place)		
	DECIMAL 1" = 1" (2 Places)	FRACTIONS 1/2" = 1" (Nearest 32nd)	1/4" = 1" (Nearest 16th)	1:1 (One place)	1:2 (Nearest mm)	1:5 (Nearest mm)
A	3.89					
B						
C						
D						
E						
F						
G						
H						

	MACHINIST STEEL RULE (Full Scale)			
	FRACTIONS (NEAREST 1/64)	DECIMAL (NEAREST .02)	METRIC (NEAREST mm)	METRIC (NEAREST 1/2 mm)
A				
B				
C				
D				
E				
F				
G				
H				

TOOLS AND EQUIPMENT
UNIT II

ASSIGNMENT SHEET #4--COMPUTE MECHANICAL DRAFTING PROBLEMS USING A HAND CALCULATOR

Directions: On engineering grid paper, compute the mechanical drafting problems using a hand calculator with trigonometry functions. You are given an example for each type of problem to be used as a guideline. Each example is immediately followed by the specific problem(s) that you need to solve.

Example A: Make calculations for centering a drawing (Figure 1)

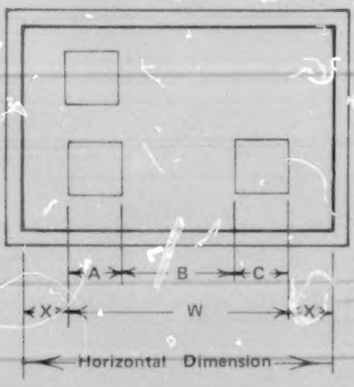


FIGURE 1

1. Find W

   A + B + C = W; if A=60, B=50, C=30, then 60 + 50 + 30 + = 140mm

2. Find K

   Horizontal dimension - W = K; if horizontal dimension = 240, then 240 - 140 = 100mm

3. Find X

   K ÷ 2 = X = left and right space; if K = 100, then X = 100 ÷ 2 = 50mm (space on both left and right)

Problem A:

1. Find X in the following layout dimensions (Figure 2)

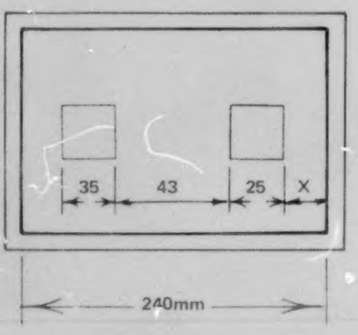


FIGURE 2

X = ____________________

ASSIGNMENT SHEET #4

2. Find X in the following layout dimensions (Figure 3)

(NOTE: Convert fractions to decimals by dividing top (numerator) by bottom (denominator.) Example: 5/8 = 5÷8 = .625.)

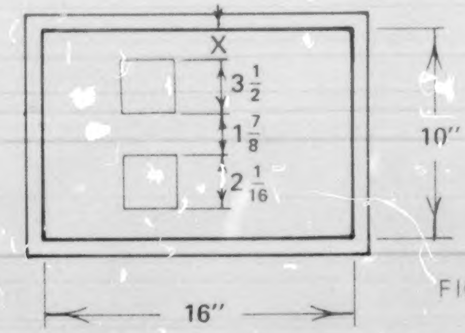

X
$3\frac{1}{2}$
$1\frac{7}{8}$
$2\frac{1}{16}$
10″
16″

FIGURE 3

X = ____________________

3. Find X in the following layout dimensions (Figure 4)

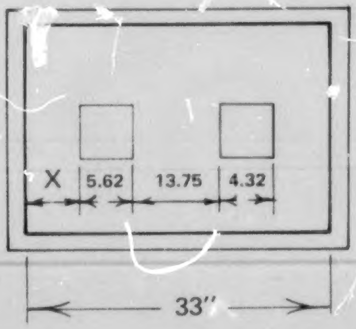

X
5.62
13.75
4.32
33″

FIGURE 4

X = ____________________

ASSIGNMENT SHEET #4

Example B: Make triangle calculations

1. Find "R" distance using the following steps on the hand calculator: (Figure 5)

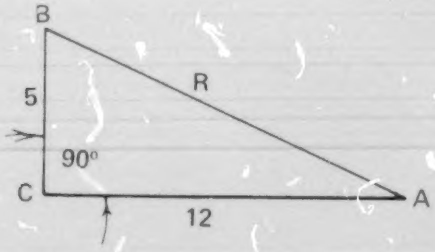


FIGURE 5

   a. $(AB)^2 = (BC)^2 + (CA)^2$

   b. $R^2 = (5)^2 + (12)^2$

   c. $R^2 = 25 + 144$

   d. $R^2 = 169$

   e. $R = \sqrt{169} = 13$

2. Find "X" distance using the following steps on the hand calculator: (Figure 6)

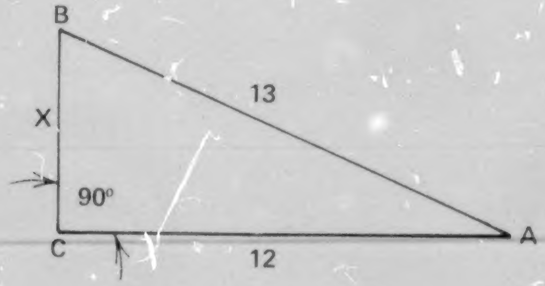


FIGURE 6

   a. $(AB)^2 = (BC)^2 + (CA)^2$

   b. $(13)^2 = (BC)^2 + (12)^2$

   c. $169 = (BC)^2 + 144$

   d. $169 - 144 = (BC)^2$

   e. $25 = (BC)^2$

   f. $\sqrt{25}$ = [illegible]C

   g. $5 = BC = X$

ASSIGNMENT SHEET #4

Problem B:

1. Calculate R (Figure 7) R = ____________________

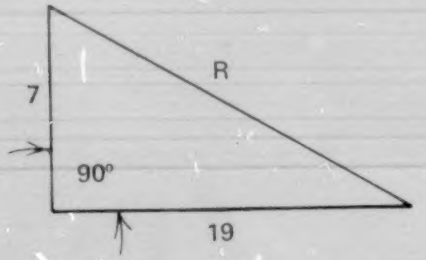


FIGURE 7

2. Calculate X (Figure 8) X = ____________________

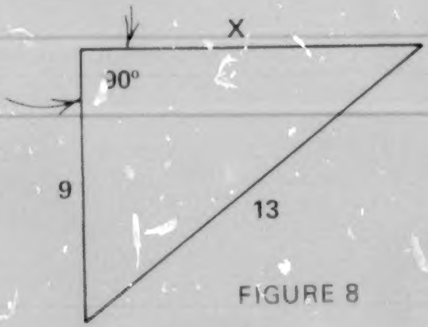


FIGURE 8

(NOTE: If you should need to find the area for triangles, use the following formula: Area = 1/2 x Opposite side x Adjacent side. See Figure 9.)

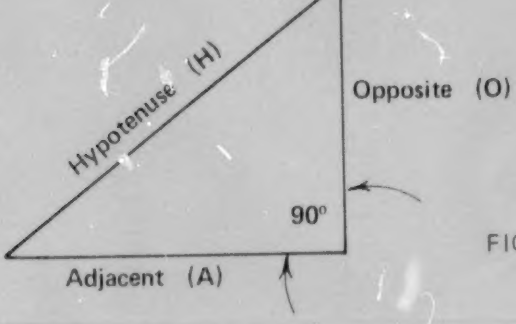

Hypotenuse (H)
Opposite (O)
90°
Adjacent (A)

FIGURE 9

ASSIGNMENT SHEET #4

(NOTE: If you should need to find the area of an oblique triangle, use the following formula: Area = 1/2 x Base x Altitude. See Figure 10.)

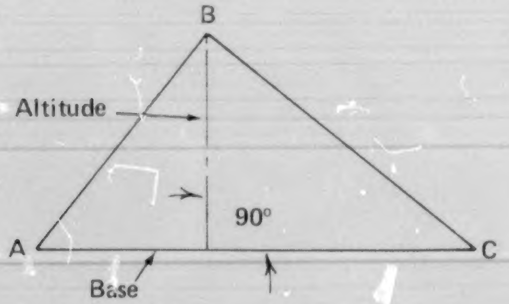


FIGURE 10

Example C: Make circle calculations by using the following formulas:

Area = $\pi R^2 = \frac{\pi(D)^2}{4}$ and Circumference = $\pi D = 2\pi R$ (Figure 11)

(NOTE: Use 3.1416 = π.)

1. Find area

   a. Use area = πR^2 and radii = 2"

      Area = 3.1416 $(2)^2$
      = 3.1416 (4)
      = 12.566

      (NOTE: Diameter = 2R.)

   b. Use area = $\frac{\pi (D)^2}{4}$

      Area = $\frac{3.1416\ (4)^2}{4}$

      = 12.566

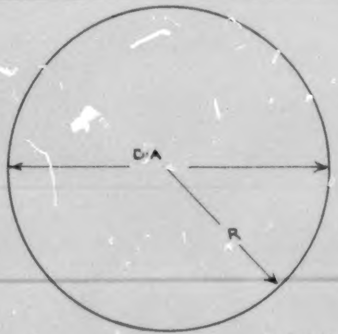


FIGURE 11

2. Find circumference

   a. Use circumference = $2\pi R$ and radii = 3"

      Circumference = 2 (3.1416) 3
      = 18.850

   b. Use circumference = πD

      Circumference = 3.1416 (6)
      = 18.850

ASSIGNMENT SHEET #4

Problem C:

1. Calculate area of a 6.32" diameter circle

A = ______________________

2. Calculate area of a 4.5" radius circle

A = ______________________

3. Calculate circumference of a 3 7/8" diameter circle

C = ______________________

4. Calculate circumference of a 1.75" radius circle

C = ______________________

Example D: Make rectangle calculations by using the following formulas:

Area = Base x Height; Diagonal = $\sqrt{(\text{Base})^2 + (\text{Height})^2}$

(NOTE: Diagonal of the rectangle and hypotenuse of the triangle formed are the same. See Figure 12.)

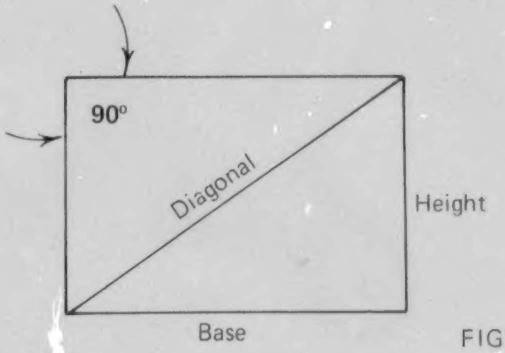


FIGURE 12

ASSIGNMENT SHEET #4

1. Find area of rectangle

   a. Base is 4mm and height is 2mm

   b. Area = Base x height
      = 4mm x 2mm
      = $8mm^2$

2. Find diagonal of rectangle

   a. Base is 4mm and height is 2mm

   b. Diagonal = $\sqrt{(Base)^2 + (Height)^2}$

      $= \sqrt{(4mm)^2 + (2mm)^2}$

      $= \sqrt{16mm^2 + 4mm^2}$

      $= \sqrt{20mm^2}$

      = 4.4721mm

Problem D:

1. Calculate area of a rectangle 7.75" x 12.32"

A = ____________________

2. Calculate diagonal of a rectangle 4.59" x 8.79"

D = ____________________

TOOLS AND EQUIPMENT
UNIT II

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A.
1. 0.871
2. 0.226
3. 0.184
4. 0.291
5. 0.086
6. 0.023
7. 0.500
8. 0.342
9. 0.047
10. 0.125
11. 0.613
12. 0.250
13. 0.012

B.
1. 6.75 mm
2. 3.68 mm
3. 8.78 mm
4. 14.26 mm
5. 10.61 mm
6. 3.85 mm

Assignment Sheet #2

A.
1. .321
2. 3.067

B.
1. 4.603
2. 1.317

C.
1. 18.22
2. 20.62
3. 6.70
4. 19.94

Assignment Sheet #3

	MECHANICAL ENGINEER SCALE			METRIC SCALE (mm) (One place)		
	DECIMAL 1" = 1" (2 Places)	FRACTIONS 1/2" = 1" (Nearest 32nd)	FRACTIONS 1/4" = 1" (Nearest 16th)	1:1 (One place)	1:2 (Nearest mm)	1:5 (Nearest mm)
A	3.89	7 25/32	15 9/16	98.8	198	494
B	3.31	6 5/8	13 1/4	84.0	168	420
C	5.39	10 25/32	21 9/16	136.9	274	680
D	.36	23/32	1 7/16	9.2	18	46
E	2.41	4 13/16	9 5/8	60.5	121	303
F	4.33	8 21/32	17 5/16	109.7	219	549
G	4.98	10 31/32	19 15/16	125.6	251	628
H	1.38	2 3/4	5 1/2	35.0	70	175

	MACHINIST STEEL RULE (Full Scale)			
	FRACTIONS (NEAREST 1/64)	DECIMAL (NEAREST .02)	METRIC (NEAREST mm)	METRIC (NEAREST 1/2 mm)
A	3 57/64	3.88	99	99.0
B	3 5/16	3.40	84	84.0
C	5 25/64	5.40	137	137.0
D	23/64	.36	9	9.0
E	2 13/32	2.40	61	60.5
F	4 21/64	2.32	110	109.5
G	4 63/64	4.98	126	125.5
H	1 3/8	1.38	35	35.0

Assignment Sheet #4

A. 1. $X = 68.5$

2. $X = 1.28$

3. $X = 4.64$

B. 1. $R = 20.2485''$

2. $X = 9.3808''$

C. 1. $A = 31.3707 \text{ in.}^2$

2. $A = 63.6173 \text{ in.}^2$

3. $C = 2.7489''$

4. $C = 10.9956''$

D. 1. $A = 95.48 \text{ in.}^2$

2. $D = 9.916$

TOOLS AND EQUIPMENT
UNIT II

JOB SHEET #1--USE A MICROMETER

I. Tools and equipment

  A. Micrometers (plain)

    1. (0-1.000") size

    2. (1.000"-2.000") size

    (CAUTION: Handle instruments with care.)

  B. Workpieces

    1. Assortment (5) fractional drill bits (new)

    2. Assortment (5) letter size drill bits (new)

    3. Assortment (5) pieces of cold rolled stock, machined parts, or hardened dowels

    4. One workpiece mounted stationary

    (NOTE: All workpieces should be numbered for reference.)

II. Procedure

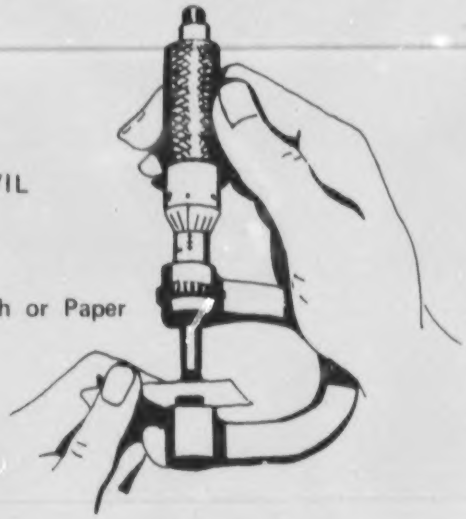
  A. Clean all workpieces to be measured and make sure they are free of burrs, nicks, or dents

  B. Number all workpieces for reference

  C. Clean the spindle and anvil of the micrometer (Figure 1)

Figure 1

CLEAN SPINDLE AND ANVIL

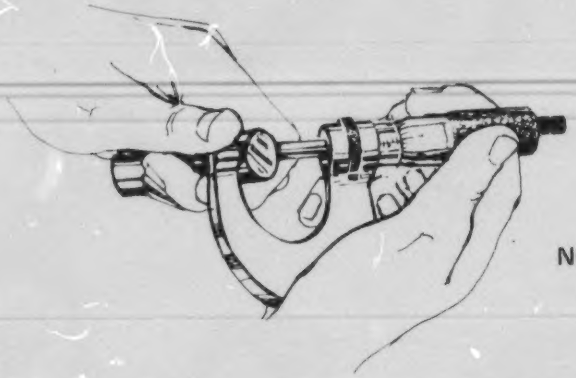


JOB SHEET #1

D. Check the micrometer at zero reference

E. Hold the micrometer in the right hand and the workpiece in the left hand to measure non-stationary objects (Figure 2)

Figure 2

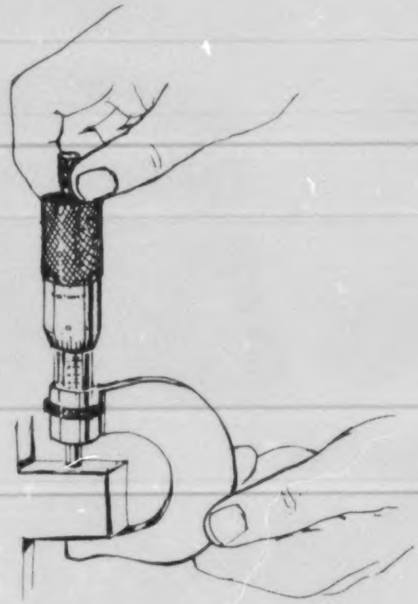


NON-STATIONARY OBJECT

F. Hold the micrometer in both hands to measure a stationary object (Figure 3)

Figure 3

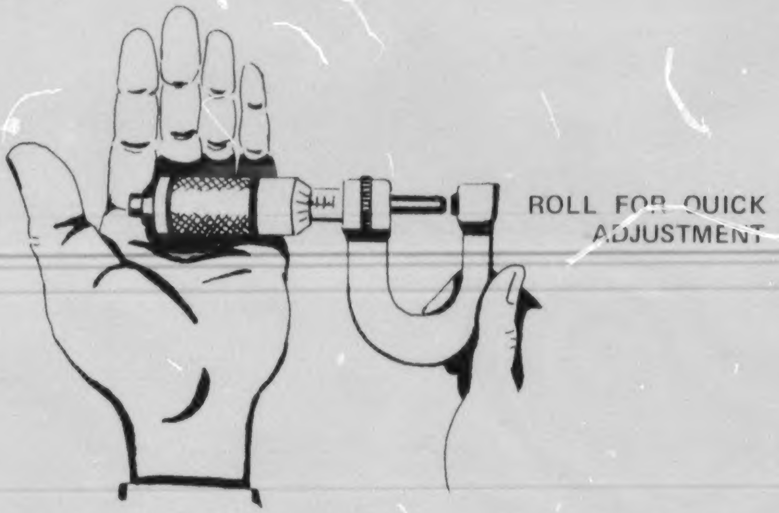
STATIONARY OBJECT



JOB SHEET #1

G. Roll micrometer along palm of hand or forearm for quick adjustment (Figure 4)

Figure 4


ROLL FOR QUICK ADJUSTMENT

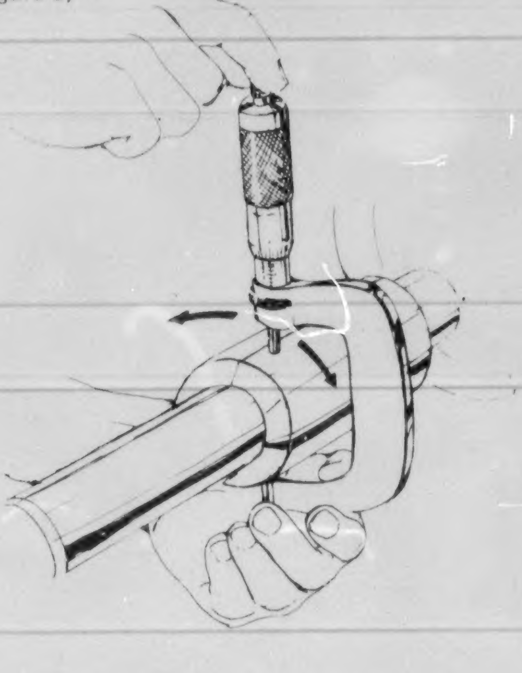
H. Place the micrometer directly over the center of the workpiece to be measured

(NOTE: Use proper size micrometer for the job.)

I. Turn the thimble of the micrometer until the anvil and spindle contact the workpiece

J. Hold the anvil steady, and move the spindle lightly over the workpiece to locate the true diameter (Figure 5)

Figure 5


WORK BACK AND FORTH TO FIND TRUE DIAMETER

JOB SHEET #1

K. Use ratchet stop or light sense of touch to determine exact measurement

L. Observe micrometer readings

(NOTE: Lock nut can be turned to hold measurement if micrometer must be removed from workpiece Spindle must be unlocked before resetting to a new measurement.)

M. List the readings according to the letter or number on the workpiece

1. Workpiece #1 ______________________________
2. Workpiece #2 ______________________________
3. Workpiece #3 ______________________________
4. Workpiece #4 ______________________________
5. Workpiece #5 ______________________________
6. Stationary workpiece __________________________

N. Leave the spindle and anvil of the micrometer open

O. Return the micrometer to its correct storage

P. Hand in listed readings to the instructor for evaluation

TOOLS AND EQUIPMENT
UNIT II

JOB SHEET #2--USE A VERNIER CALIPER

I. Tools and equipment

   A. Vernier caliper--Inch, 25 or 50 divisions

   B. Vernier caliper--Metric

   (NOTE: A combination inch and metric vernier caliper may be used.)

   (CAUTION: Handle instruments with care.)

   C. Workpieces

      1. Assortment (5) pieces of cold rolled stock, machine parts, or hardened dowels

      2. One workpiece mounted stationary

      (NOTE: All workpieces should be numbered for reference.)

II. Procedure

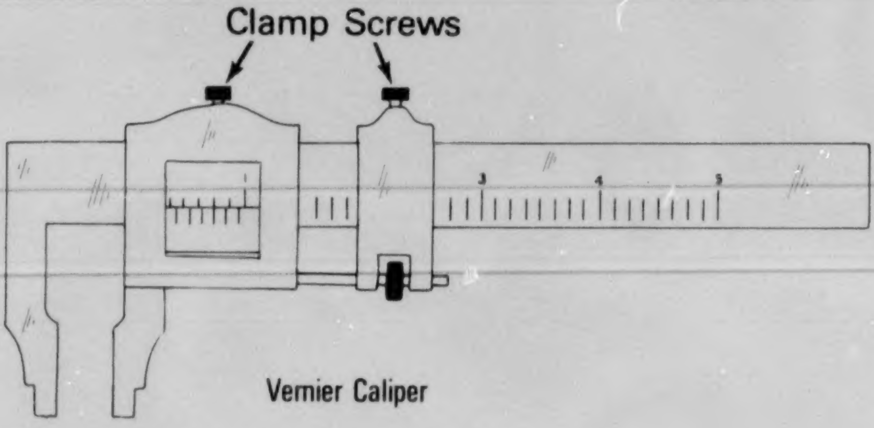
   A. Clean all workpieces to be measured and make sure they are free of burrs, nicks, or dents

   B. Number all workpieces for reference

   C. Clean the vernier caliper's jaws

   D. Slide movable jaws by releasing clamp screws (Figure 1)

FIGURE 1



Vernier Caliper

JOB SHEET #2

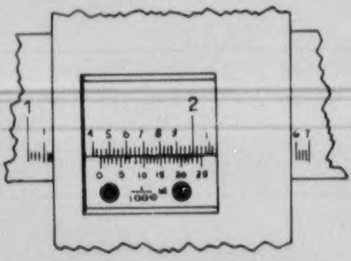
E. Slide jaws over workpieces to be measured

(NOTE: Use fine adjustment nut to get a more accurate reading.)

F. Tighten clamp screws with fingers and remove workpiece, or in the case of stationary workpiece, remove caliper

G. Read an inch vernier caliper--25 divisions (Figure 2)

FIGURE 2



1. Read to the left of the vernier scale zero the last *large* number above the main scale for the number of whole inches

   Example: 1.000"

2. Read to the left of the vernier scale zero the last *small* number above the main scale for the number in tenths

   Example: 4

3. Multiply this number by .100

   Example: 4 x .100 = .400"

4. Count the number of graduations from the small number to zero on the vernier scale

   Example: 1

5. Multiply this number by .025

   Example: 1 x .025 = .025"

6. Look at the graduations on the vernier scale and the graduations on the bar; find which two graduation lines line up

7. Count over from zero to where the two line up

8. Multiply this number by .001

   Example: 11 x .001 = .011

JOB SHEET #2

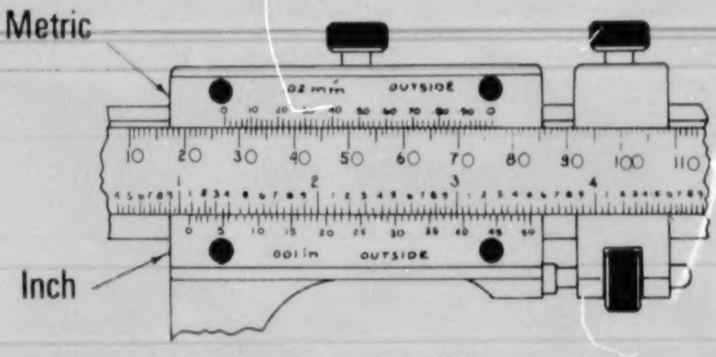
9. Add up each part

   Example:

	1.000
	.400
	.025
	.011
Answer	1.436"

H. Read an inch vernier caliper--50 divisions (Figure 3)

FIGURE 3


Metric
.02 mm
OUTSIDE
0 10 20 30 40 50 60 70 80 90 0
10 20 30 40 50 60 70 80 90 100 110
1 2 3 4
0 5 10 15 20 25 30 35 40 45 50
.001 in
OUTSIDE
Inch

1. Read to the left of the main inch vernier scale zero the last *large* number above the main inch vernier plate on the bar for the number of whole inches

   Example: 1.000

2. Read to the left of the vernier scale zero the last *small* number above the main inch vernier plate on the bar for the number in tenths

   Example: 0 x .1 = 000

3. Count the number of graduations from small number to zero on the vernier scale

4. Multiply this number by .050

   Example: 1 x .050 = .050

5. Look at the graduations on the vernier scale and the graduations on the bar; find which two graduation lines line up

6. Count over from zero to where the two line up

7. Multiply this number by .001

   Example: 14 x .001 = .014

JOB SHEET #2

8. Add up each part

   Example:
   1.000
   .000
   .050
   .014
   Answer 1.064"

I. Read a metric vernier caliper (Figure 3)

1. Read to the left of the main metric vernier scale zero the number on the bar; the number represents the number of millimeters

   Example: 20mm

   (NOTE: In Transparency 19, the number must be multiplied by 10 to get the number of millimeters.)

2. Read the number of graduation lines from the number to zero

3. Multiply this number by 1mm

   Example: 7 x 1 = 7mm

4. Look at the graduations on the main metric vernier scale and the graduations on the bar; find which two graduation lines line up

5. Count over from zero to where the two line up; each graduate is .02

   Example: .42

6. Add up each part

   Example:
   20. mm
   7. mm
   .42mm
   Answer 27.42mm

J. List the readings for the inch or metric vernier caliper according to the number on the workpiece

	INCH	METRIC
1. Workpiece #1		
2. Workpiece #2		
3. Workpiece #3		
4. Workpiece #4		
5. Workpiece #5		
6. Stationary workpiece		

JOB SHEET #2

K. Return calipers to their correct storage

L. Hand in listed readings to the instructor for evaluation

TOOLS AND EQUIPMENT
UNIT II

NAME ______________________________

TEST

1. Match the terms on the right with the correct definitions.

   _____a. Instrument used as a standard of reference when drawing an object to a proportional size

   _____b. A thin, flat, plastic tool with various size openings of different shapes used to expedite the drawing of standard features

   _____c. Arrangement of a sequence of operations

   _____d. Instruments used by machinists to measure and gage products

   _____e. Calculating device to solve mathematical problems

   _____f. Preprinted letters, symbols, and shading that can be rubbed on or cut out for drawings to save drafting time

   _____g. Points, lines, or other geometric shapes assumed to be exact from which the location or geometric form of features of a part may be estimated

   1. Template
   2. Precision instruments
   3. Transfer artwork
   4. Datums
   5. Scale
   6. Hand calculator
   7. Logic

2. Complete the following list of mechanical templates.

   a. General purpose

      1. ______________________________

      2. ______________________________

   b. Welding

   c. Threaded fasteners

      1. ______________________________

      2. ______________________________

   d. Springs

   e. Three dimensional

      1. ______________________________

      2. ______________________________

3. Match the machinist precision measuring instruments on the right with the correct functions.

_____a. Accurate inside measurements

_____b. Depth of slots or holes from datum surfaces

_____c. Plain external dimension for "go" or "no go" gaging

_____d. Comparison of finished part to a master or lines on a screen

_____e. Accurate angle measurements

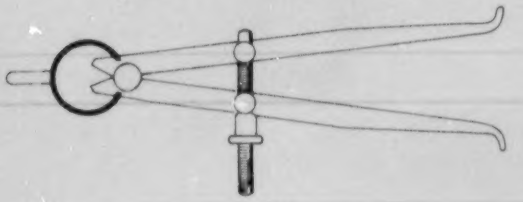
_____f. Alignment, eccentricity, or deviations on surfaces

_____g. Dimension transfers and circle scribes

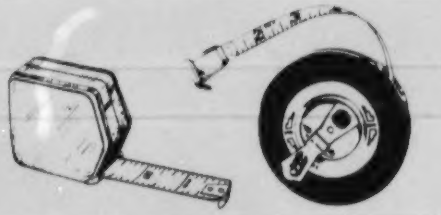
_____h. Internal dimensions of holes for "go" or "no go" gaging

1. Snap gage
2. Plug gage
3. Inside micrometer
4. Depth micrometer
5. Sine bar
6. Divider
7. Dial indicator gage
8. Optical comparator

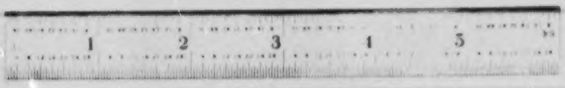
4. Identify types of welding measuring instruments.



a. ______________________________

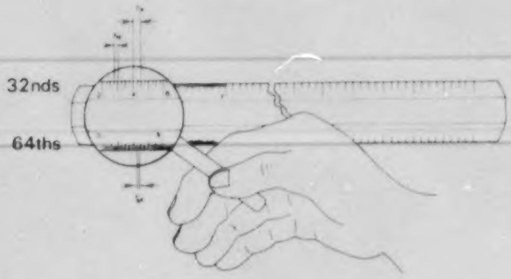


b. ______________________________

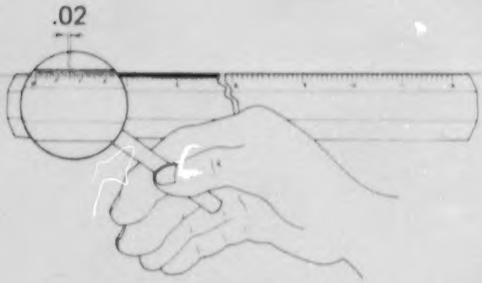


c. ______________________________

5. Identify types of scales used in mechanical drafting.



a. ______________________________



b. ______________________________

6. Name the primary metric unit of measurement used in mechanical drafting.

____

7. Classify the scales used in mechanical drafting by placing an "MEF" for Mechanical Engineer, Fractions; "MED" for Mechanical Engineer, Decimal; "MSRD" for Machinist Steel Rule, Decimal; "MSRM" for Machinist Steel Rule, Metric; and "M" for Metric scale in the appropriate blanks.

______a. 1:3

______b. 50 parts per inch--Each division equals .02"

______c. 32 parts per inch--Each division equals 1/32"

______d. 1/4" = 1"

______e. 1:5

______f. 1/2 millimeter--Each division equals .5mm

______g. 64 parts per inch--Each division equals 1/64"

______h. 1:10

______i. 1:1

______j. 1/2" = 1"

8. Complete the following list of hand calculator functions.

a. Primary

1. Multiply
2. Divide
3. ______________________________
4. ______________________________

b. Secondary

  1. Square
  2. Logarithm
  3. Trigonometric
  4. Storage
  5. Angular mode
  6. Hyperbolic
  7. ______________________________
  8. ______________________________
  9. ______________________________

9. Distinguish between the types of keyboard sequences used in hand calculators by placing an "X" next to the characteristics of the Lukasciewicz keyboard sequence.

______a. Is easy to master

______b. Usually takes fewer steps

______c. Is referred to as "reverse Polish"

______d. Sometimes takes more steps

______e. Has operational stack

10. Demonstrate the ability to:

a. Read micrometer settings.

b. Read vernier calipers.

c. Measure with scales.

d. Compute mechanical drafting problems using a hand calculator.

e. Use a micrometer.

f. Use a vernier caliper.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

TOOLS AND EQUIPMENT
UNIT II

ANSWERS TO TEST

1. a. 5
   b. 1
   c. 7
   d. 2
   e. 6
   f. 3
   g. 4

2. Any two of the following under each category:

   a. 1. Circles
      2. Squares
      3. Arrows
      4. Hexagons
      5. Octagons
      6. Triangles

   c. 1. Nuts
      2. Bolts
      3. Screws
      4. Threads

   e. 1. Projection ellipses
      2. Isometric ellipses
      3. Isometric hexagon bolt heads and nuts
      4. Projection hexagon bolt heads and nuts

3. a. 3
   b. 4
   c. 1
   d. 8
   e. 5
   f. 7
   g. 6
   h. 2

4. a. Inside caliper
   b. Tapes
   c. Steel rule

5. a. Machinist steel rule (fractions)
   b. Mechanical engineer scale

6. Millimeter

7. a. M
   b. MSRD or MED
   c. MSRF
   d. MEF
   e. M
   f. MSRM
   g. MSRF
   h. M
   i. M
   j MEF

8. List should include:

   a. Under primary--add, subtract
   b. Under secondary--reciprocal, square root, antilogarithm

9. b, c, e

10. Evaluated to the satisfaction of the instructor

REFERENCE MATERIALS
UNIT III

UNIT OBJECTIVE

After completion of this unit, the student should be able to read reference materials and ANSI standards. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to reference materials with the correct definitions.
2. List manufacturing catalogs that contain product information literature.
3. Complete a list of mechanical standards references.
4. Select mechanical drafter and designer handbooks.
5. Name standards found in an ANSI drafting manual.
6. List general types of standard parts specified by ANSI.
7. Distinguish between ANSI miscellaneous standards.
8. Select ANSI metric standard fasteners references.
9. Demonstrate the ability to:
    a. Determine manufacturer of mechanical components from *Thomas Register*.
    b. Write a letter requesting product literature for mechanical components.
    c. Write a technical report using reference materials.

REFERENCE MATERIALS
UNIT III

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and assignment sheets.

III. Make transparency.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Have students go to their libraries and find out what reference indexes are available.

VII. Require that students list all reference books in drawing room.

VIII. Suggest that students go visit a welding shop and machine shop and find out what references are in use.

IX. Tour an engineering drafting room and have students take notes of references being used.

X. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet

  B. Information sheet

  C. Transparency Master 1--Mechanical Standards References

  D. Assignment sheets

    1. Assignment Sheet #1--Determine Manufacturer of Mechanical Components from *Thomas Register*

    2. Assignment Sheet #2--Write a Letter Requesting Product Literature for Mechanical Components

    3. Assignment Sheet #3--Write a Technical Report Using Reference Materials

  E. Test

  F. Answers to test

II. References:

A. *Catalog of American National Standards Institutes*. New York 10018: ANSI, 1981.

B. *Thomas Register of American Manufacturers*. New York: Thomas Publishing Co., 1981.

C. *Mac Rae's Blue Book*. Chicago: Mac Rae Publishing Co., 1981.

D. *Oklahoma Directory of Manufacturers and Products*. Oklahoma City: Oklahoma Industrial Development Department, 1981.

(NOTE: Each state may have one available.)

E. Beakley, George and Ernest Chilton. *Introduction to Engineering Design and Graphics*. New York: Macmillan Publishing Co., 1973.

III. Additional references:

A. *ASME Handbook*. New York: McGraw-Hill Book Co., 1980.

B. Calvin, F.H. and D.A. Stanley. *American Machinist's Handbook*. New York: McGraw-Hill Book Co., 1979.

C. Tweney, C.F. and L.E. Hughes. *Chambers Technical Dictionary*. New York: Macmillan Publishing Co., 1959.

D. Kubokawa, Charles. *Databook for Human Factors Engineering*. Moffetfield, CA: NASA, 1969.

E. Dudley, D.W. *Gear Handbook*. New York: McGraw-Hill Book Co., 1962.

F. Boumeister, T. and L.S. Marks. *Standard Handbook for Mechanical Engineers*. New York: McGraw-Hill Book Co., 1958.

G. Carson, G.B. *Production Handbook*. 2nd edition. New York: Ronald Press Co., 1958.

H. Weisman, Charlotte, ed. *Welding Handbook*. Miami, FL: American Welding Society, 1976.

I. *SAE Automotive Drafting Standards*. New York: Society of Automotive Engineers, 1963.

J. *SAE Handbook*. New York: Society of Automotive Engineers, 1976.

K. *SME Tool and Manufacturer's Engineer's Handbook*. New York: McGraw-Hill Book Co., 1980.

L. Damon, Albert, et. al. *The Human Body in Equipment Design*. Cambridge, MA: Harvard University Press, 1966.

M. Morgen, Clifford T. *Human Engineering Guide to Equipment Design*. Washington, D.C.: U.S. Department of Defense, 1972.

N. Oberg, Erik and F.D. Jones. *Machinery's Handbook*. New York, NY 10016: Industrial Press, Inc., 1978.

REFERENCE MATERIALS
UNIT III

INFORMATION SHEET

I. Terms and definitions

   A. ANSI (American National Standards Institute)--Organization which identifies industrial and public needs for national standards and which coordinates their development

   B. Product catalog--Compiled booklet of product literature information including specifications of parts and subassemblies and assemblies of products for consumers and manufacturers to order and/or specify on parts list

   C. Standard parts--Hardware such as bolts, screws, nuts, washers, keys, gears, and pins for use on subassemblies and assemblies specified on parts lists

   D. Handbook--Reference book or manual containing directions, specifications, and tables to aid in the design and drafting of manufactured products

   E. Standard--Specification, test method, definition, classification, publication, or practice that has been approved by a committee to regulate or control manufacturing

II. Manufacturing catalogs that contain product information literature

   A. *Materials Selector Issue*

      (NOTE: This catalog contains materials used in design engineering.)

   B. *Thomas Register*

      (NOTE: This catalog contains products and service information.)

   C. *Mac Rae's Blue Book*

      (NOTE: In this catalog products are classified.)

   D. *Directory of Manufacturers*

      (NOTE: This catalog is available by individual states from the industrial development departments.)

III. Mechanical standards references (Transparency 1)

   A. ANSI (American National Standards Institute)

   B. ASME (American Society of Mechanical Engineers)

   C. ASTM (American Society for Testing and Materials)

   D. SAE (Society of Automotive Engineers)

INFORMATION SHEET

IV. Mechanical drafter and designer handbooks

(NOTE: Complete author and publication information is included in instructor's manual.)

A. *American Machinist's Handbook*

B. *ASME Handbook*

C. *Chambers Technical Dictionary*

D. *Databook for Human Factors Engineering*

E. *Gear Handbook*

F. *The Human Body in Equipment Design*

G. *Human Engineering Guide to Equipment Design*

H. *Machinery's Handbook*

I. Production Handbook

J. SAE Automotive Drafting Standards

K. SAE Handbook

L. Standard Handbook for Mechanical Engineers

M. *SME Tool and Manufacturer's Engineer's Handbook*

N. *Welding Handbook*

V. Standards found in an ANSI drafting manual

(NOTE: The numbers in parentheses are the numbers referred to by ANSI standards.)

A. *Drawing Sheet Size and Format* (Y14.1-1975)

B. *Line Conventions and Lettering* (Y14.2-1979)

C. *Multi and Sectional View Drawings* (Y14.3-1975)

D. *Pictorial Drawings* (Y14.4-1957)

E. *Dimensioning and Tolerancing* (Y14.5-1973)

F. *Screw Threads* (Y14.6-1978)

INFORMATION SHEET

G. *Gears, Splines, and Serrations* (Y14.7-1978)

H. *Gear Drawing Standards* (Y14.7.1-1971)

I. *Forgings* (Y14.9-1958)

J. *Metal Stampings* (Y14.10-1959)

K. *Plastics* (Y14.11-1958)

L. *Mechanical Assemblies* (Y14.14 1961)

M. *Electrical and Electronics* (Y14.15-1966)

N. *Fluid Power Diagrams* (Y14.17-1966.)

O. *Dictionary of Terms for Computer-Aided Preparation of Product Definition Data* (Y14.26.3-1975)

P. *Chassis Frames* (Y14.32.1-1974)

Q. *Digital Representation of Physical Object Shapes* (Y14, Report #1)

R. *Guideline for Documenting of Computer Systems Used in Computer-Aided Preparation of Product Definition Data--User Instructions* (Y14, Report #2)

S. *Guideline for Documenting of Computer Systems Used in Computer-Aided Preparation of Product Definition Data--Design Requirements* (Y14, Report #3)

(NOTE: Another common standard is *Abbreviations* (Y1.1-1974), but this is not commonly found in a manual of drafting standards.)

VI. General types of standard parts specified by ANSI

A. Bolts and screws

1. *Hexagon or Slotted Head Cap Screws, Square Head or Slotted Set Screws* (B18.6.2-1972)
2. *Plow Bolts* (B18.9-1958, R1971)
3. *Round Head Bolts* (B18.5-1971)
4. *Slotted and Recessed Head Machine Screws and Machine Screw Nuts* (B18.6.3-1972)
5. *Slotted and Recessed Head Wood Screws* (B18.6.1-1972)
6. *Socket Cap, Shoulder, and Set Screws* (B18.3-1976)
7. *Square and Hex Bolts and Screws* (B18.2.1-1972)

INFORMATION SHEET

8. *Square and Hex Nuts* (B18.2.2-1972)
9. *Track Bolts and Nuts* (B18.10-1963, R1975)

B. Gears

1. *System for Straight Bevel Gears* (B6.13-1965, R1974)
2. *Tooth Proportions for Coarse-Pitch Involute Spur Gears* (B6.1-1968, R1974)
3. *Tooth Proportions for Fine-Pitch Involute Spur and Helical Gears* (B6.7-1967, R1974)

C. Keys and pins

1. *Machine Pins* (B5.20-1958)
2. *Woodruff Keys and Keyseats* (B17.2-1967, R1972)

D. Rivets

1. *Large Rivets* (B18.1.2-1972)
2. *Small Solid Rivets* (B18.1.1-1972)

E. Washers

1. *Lock Washers* (B18.21.1-1972)
2. *Plain Washers* (B18.22.2-1965)

VII. ANSI miscellaneous standards

A. Dimensioning and surface finish

1. *Preferred Limits and Fits for Cylindrical Parts* (B4.1-1967, R1974)
2. *Rules for Rounding Off Numerical Values* (Z25.1-1940, R1961)
3. *Scale to Use with Decimal-Inch Dimensioning* (Z75.1-1955)
4. *Surface Texture* (B46.1-1962, R1971)
5. *Decimal Inch* (B87.1-1965)
6. *Metric Practice* (E380.76)
7. *Tolerance for Metric Dimensional Products, General* (B4.3-1978)

INFORMATION SHEET

B. Small tools and machine elements

1. *Jig Bushings* (B94.33-1974)
2. *Machine Tapers* (B5.10-1963, R1972)
3. *Milling Cutters and End Mills* (B94.19-1968)
4. *Reamers* (B94.2-1971)
5. *T-Slots* (B5.1-1975)
6. *Tops, Cut, and Ground Threads* (B94.9-1971)
7. *Twist Drills, Straight Shank, and Taper Shank* (B94.11-1967, R1972)

VIII. ANSI metric standard fasteners references

A. *Hexagon Socket Head Shoulder Screws Metric* (B18.3.3M-1979)

B. *Hex Socket Button Head Cap Screws Metric* (B18.3.4N-1979)

C. *Metric Formed Hex Screws* (B18.2.3.2M 1979)

D. *Metric Heavy Hex Bolts* (B18.2.3.6M 1979)

E. *Metric Heavy Hex Screws* (B18.2.3.3M 1979)

F. *Metric Heavy Hex Structural Bolts* (B18.2.3.7M 1979)

G. *Metric Hex Bolt* (B18.2.3.5M 1979)

H. *Metric Hex Cap Screws* (B18.2.3.1M 1979)

I. *Metric Hex Lag Screws* (B18.2.3.8M 1979)

J. *Metric Series Hexagon Keys and Bits* (B18.3.2M 1979)

K. *Metric Series Hexagon Socket Set Screws* (B18.3.6M 1979)

L. *Metric Screw Threads MJ Profile* (B1.21M 1978)

M. *Retaining Rings* (B27.8M 1978)

Mechanical Standards References

American National Standards Institute

ANSI

American Society of Mechanical Engineers

ASME

American Society for Testing and Materials

ASTM

Society of Automotive Engineers

SAE

REFERENCE MATERIALS
UNIT III

ASSIGNMENT SHEET #1--DETERMINE MANUFACTURER OF MECHANICAL COMPONENTS FROM *THOMAS REGISTER*

Directions: Using the *Thomas Register*, write the name and address of one manufacturer for the following products and/or parts.

A. Electric motor

B. Machine screws

C. Cams

D. Spring lock washer

E. Gears

F. Solar collector

G. Shear for sheet metal

H. Pump

REFERENCE MATERIALS
UNIT III

ASSIGNMENT SHEET #2--WRITE A LETTER REQUESTING PRODUCT LITERATURE FOR MECHANICAL COMPONENTS

Directions: Select one of the addresses from Assignment Sheet #1 or another address from the *Thomas Register*. Write a letter to the manufacturer requesting information concerning product specifications and cost. After instructor approves rough copy, type and mail. Those items in italics in the following example are what you should fill in with your information.

Example:

425 Elm Street
Stillwater, OK 74074

February 17, 1983

Enerpac
Sales Office
Butler, WI 53007

Sales Representative:

I am a student at *Indian Meridian Area Vocational-Technical School.* I am in the process of designing equipment. Please send me product literature, specifications, and cost for *Hi-tonnage jacking cylinders.* I am not interested in purchasing your product at this time, but may consider it in the future.

Thank you for your consideration.

Sincerely,

Joe Smith

Joe Smith

REFERENCE MATERIALS
UNIT III

ASSIGNMENT SHEET #3--WRITE A TECHNICAL REPORT USING REFERENCE MATERIALS

Directions: Write a technical report in an area which interests you. Use reference materials found in available indexes. Restrict length to 5 handwritten (2-2 1/2 typed) pages. Report should include the following:

1. Title page (subject, your name, date)
2. Introduction (what your paper will cover, why you chose this area)
3. Body (logical presentation of information discovered while researching)
4. Conclusion (brief summary of what you have learned, final remarks)
5. References (at least three)

   (NOTE: Books are categorized in the library according to the author, title, and subject in the card catalogs. Two good indexes to find articles in the library are *Engineering Index* and *Applied Science and Technology Index*.)

REFERENCE MATERIALS
UNIT III

NAME ______________________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. Hardware such as bolts, screws, nuts, washers, keys, gears, and pins for use on subassemblies and assemblies and specified on parts lists

_____b. Organization which identifies industrial and public needs for national standards and which coordinates their development

_____c. Reference book or manual containing directions, specifications, and tables to aid in the design and drafting of manufactured products

_____d. Compiled booklet of product literature information including specifications of parts and subassemblies and assemblies of products for consumers and manufacturers to order and/or specify on parts lists

_____e. Specification, test method, definition, classification, publication, or practice that has been approved by a committee to regulate or control manufacturing

1. ANSI
2. Product catalog
3. Standard parts
4. Handbook
5. Standard

2. List two manufacturing catalogs that contain product information literature.

a. ______________________________

b. ______________________________

3. Complete the following list of mechanical standards references.

a. ASME

b. SAE

c. ______________________________

d. ______________________________

4. Select mechanical drafter and designer handbooks by placing an "X" in the appropriate blanks.

______a. *Chambers Technical Dictionary*

______b. *Standard Handbook for Mechanical Engineers*

______c. *Small Engine Repair*

______d. *American Machinist Handbook*

______e. *ASME Handbook*

______f. *Four-Stroke Cycle Engine Mechanic Handbook*

______g. *SAE Handbook*

______h. *Databook for Human Factors Engineering*

5. Name five standards found in an ANSI drafting manual.

a. ____

b. ____

c. ____

d. ____

e. ____

6. List four general types of standard parts specified by ANSI.

a. ____

b. ____

c. ____

d. ____

7. Distinguish between ANSI miscellaneous standards by placing an "X" next to the standards for dimensioning and surface finish and an "O" next to the standards for small tools and machine elements.

______a. *Preferred Limits and Fits for Cylindrical Parts*

______b. *Machine Tapers*

______c. *T-Slots*

______d. *Metric Practice*

______e. *Tolerance for Metric Dimensional Products, General*

______f. *Reamers*

8. Select ANSI metric standard fasteners references by placing an "X" in the appropriate blanks.

   ______a. *Metric Heavy Hex Screws*

   ______b. *Retaining Rings*

   ______c. *Metric Hex Lag Screws*

   ______d. *Slotted and Recessed Head Wood Screws*

9. Demonstrate the ability to:

   a. Determine manufacturer of mechanical components from *Thomas Register*.

   b. Write a letter requesting product literature for mechanical components.

   c. Write a technical report using reference materials.

   (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

REFERENCE MATERIALS
UNIT III

ANSWERS TO TEST

1. a. 3 d. 2
   b. 1 e. 5
   c. 4

2. Any two of the following:

   a. *Materials Selector Issue*
   b. *Thomas Register*
   c. *Mac Rae's Blue Book*
   d. *Directory of Manufacturers*

3. c. ANSI
   d. ASTM

4. a, b, d, e, g, h

5. Any five of the following:

   a. *Drawing Sheet Size and Format*
   b. *Line Conventions and Lettering*
   c. *Multi and Sectional View Drawings*
   d. *Pictorial Drawings*
   e. *Dimensioning and Tolerancing*
   f. *Screw Threads*
   g. *Gears, Splines, and Serrations*
   h. *Gear Drawing Standards*
   i. *Forgings*
   j. *Metal Stampings*
   k. *Plastics*
   l. *Mechanical Assemblies*
   m. *Electrical and Electronics*
   n. *Fluid Power Diagrams*
   o. *Dictionary of Terms for Computer-Aided Preparation of Product Definition Data*
   p. *Chassis Frames*
   q. *Digital Representation of Physical Object Shapes*
   r. *Guideline for Documenting of Computer Systems Used in Computer-Aided Preparation of Product Definition Data--User Instructions*
   s. *Guideline for Documenting of Computer Systems Used in Computer-Aided Preparation of Product Definition Data--Design Requirements*

6. Any four of the following:

   a. Bolts and screws
   b. Gears
   c. Keys and pins
   d. Rivets
   e. Washers

7. a. X
   b. O
   c. O
   d. X
   e. X
   f. O

8. a, b, c

9. Evaluated to the satisfaction of the instructor

LAYOUTS AND WORKING DRAWINGS
UNIT IV

UNIT OBJECTIVE

After completion of this unit, the student should be able to draw a design layout and draw a set of working drawings. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to layouts and working drawings with the correct definitions.
2. Distinguish between standard and additional information on a title form.
3. Identify information on a revision block.
4. List information on a bill of materials/parts list.
5. Arrange in order the stages of the design process.
6. Select true statements concerning design layouts.
7. List basic elements of a design layout sketch.
8. Name the three standard parts of a detail drawing.
9. Match parts of an assembly drawing with the correct functions.
10. Select information found on outline or installation assemblies.
11. Select information found on welding assembly drawings.
12. Select characteristics of forging drawings.
13. Select information found on a pattern or casting drawing.
14. Demonstrate the ability to:
    a. Draw a design layout.
    b. Draw a set of detail drawings.
    c. Draw an assembly drawing.
    d. Complete a detailed title block and revision block.
    e. Complete a parts list.
    f. Make a drawing revision.

LAYOUTS AND WORKING DRAWINGS
UNIT IV

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and assignment sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Assign students appropriate projects that can be used for all assignment sheets.

VII. Select the title block that you want the students to use in this particular class, and give instructions on filling it out.

VIII. Make appropriate changes in the student's drawing sheets from Assignment Sheets #2, #3, or #4 to enable the students to make revisions for Assignment Sheet #6.

IX. Furnish a model or prototype for use in discussing objective V, item D, the design process.

X. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet

  B. Information sheet

  C. Transparency masters

    1. TM 1--Engineering Change Notice

    2. TM 2--Title Forms

    3. TM 3--Revisions

    4. TM 4--Bill of Materials/Parts List

    5. TM 5--Design Process

    6. TM 6--Design Layout

7. TM 7--Detail Drawing
8. TM 8--Assembly Drawing
9. TM 9--Detail Assembly Drawing
10. TM 10--Outline or Installation Assembly
11. TM 11--Welding Assembly Drawing
12. TM 12--Forging Drawing
13. TM 13--Casting Drawing

D. Assignment sheets

1. Assignment Sheet #1--Draw a Design Layout
2. Assignment Sheet #2--Draw a Set of Detail Drawings
3. Assignment Sheet #3--Draw an Assembly Drawing
4. Assignment Sheet #4--Complete a Detailed Title Block and Revision Block
5. Assignment Sheet #5--Complete a Parts List
6. Assignment Sheet #6--Make a Drawing Revision

E. Test

F. Answers to test

II. References

A. Brown, Walter C. *Drafting for Industry*. South Holland, IL 60473: Goodheart-Willcox Co., Inc., 1974.

B. Dygdon, John Thomas and Henry Cecil Spencer. *Basic Technical Drawing*. New York 10022: Macmillan Publishing Co., Inc. 1968.

C. Giesecke, Frederick E., et. al. *Technical Drawing*. New York 10022: Macmillan Publishing Co., Inc., 1980.

D. Jensen, Cecil and Jay Helsel. *Engineering Drawing and Design*. New York: Gregg Division/McGraw-Hill Book Co., 1979.

E. American National Standards Institute. *Drawing Sheet Size and Format*. Y14.1-1975. New York 10017: American Society of Mechanical Engineers, 1975.

F. American National Standards Institute. *Forgings*, Y14.9-1958. New York 10017: American Society of Mechanical Engineers, 1958.

LAYOUTS AND WORKING DRAWINGS
UNIT IV

INFORMATION SHEET

I. Terms and definitions

A. Title--Name of the object or project

(NOTE: The title is the second most important size of lettering on the drawing.)

B. Title form--Standardized place to show all information not shown with notes and dimensions on the drawing

C. Revision--Change made on a drawing

(NOTE: This change may be due to drafting error, design change or error, production change or error, or customer change or error.)

D. Revision form--Area to show all information related to a drawing revision

E. Zoning--Equal intervals along the margins labeled with numbers along the horizontal margin and with letters along the vertical margin for locating an area on a drawing

F. Bill of materials/parts list--Itemized list of parts shown with an assembly drawing

(NOTE: Parts may be raw stock, purchased parts, or fasteners.)

G. Design process--Organized method to combine scientific principles, standard parts, and resources into the solution of a problem

H. Detail drawing--Drawing containing the necessary information to completely manufacture a single part or one stage of a single part

I. Design layout--Accurate drawing of all parts in working positions showing clearances of moving parts, ease of assembly, and ease of serviceability

J. Assembly drawing--Drawing showing all parts in their working position

K. Detail assembly drawing--Combined detail and assembly drawing used when the details are simple enough for all parts to be shown and dimensioned clearly while shown in assembled positions

(NOTE: This drawing is used on aircraft subassemblies, drawings of jigs and fixtures, and welding drawings.)

L. Engineering change notice (ECN)--An approved change to a drawing caused by a change in design, tool changes, errors in design or production, and customer changes (Transparency 1)

(NOTE: ECN's are reflected in the revision record on the drawing.)

INFORMATION SHEET

M. Forging drawing--A detail drawing of a workpiece to be forged in dies

N. Casting drawing--A detail drawing of a workpiece to be cast

II. Information on a title form (Transparency 2)

(NOTE: The following information is generally found in a title form as a title block or title strip.)

A. Standard information

1. Name of the object represented
2. Name and address of the industry
3. Name and address of the client, if any
4. Number of drawing which may include sheet letter size
5. Revision letter
6. Signature of drafter with date of completion
7. Signature of checker with date of completion
8. Signature of designer, engineer, or other official and date approved
9. Predominate scale of drawing
10. Sheet number for multiple sheets

B. Additional information

1. Tolerances
2. Material
3. Heat treatment
4. Quantity
5. Finish
6. Hardness
7. Weight
8. Superseding note
9. Company logos
10. Other peculiarities of the product

INFORMATION SHEET

III. Information on a revision block (Transparency 3)

- A. Letter or number of change(s)
- B. Description of correction or change
- C. Person making change
- D. Person checking change
- E. Date of change
- F. Zone for location of change

IV. Information on a bill of materials/parts list (Transparency 4)

- A. Standard information
    1. Item number referring to assembly drawing

       (NOTE: Item numbers are sometimes referred to as dash numbers.)
    2. Part name
    3. Number required
    4. Material from which part is made
- B. Additional information
    1. Stock number
    2. Description or nomenclature
    3. Address of vender
    4. Unit of measure

       (NOTE: These units include grams, pieces, feet, pounds, or gallons.)
    5. Group subassembly where used
    6. Approval
    7. Release date
    8. Originator
    9. Revision

INFORMATION SHEET

10. Stock size

11. Pattern number

12. Weight

V. Stages of the design process (Transparency 5)

A. Problem identification

(NOTE: This stage is the plan of action which includes available information, parameters for time, cost, defined function, limits, and market potential.)

B. Preliminary ideas and concepts

(NOTE: This stage includes brainstorming from technical literature, reports, design and trade journals, patents, and existing products. A notebook should be started and up-dated to include signatures and dates of inventors and witnesses.)

C. Refinement of solutions

(NOTE: In this stage the design layouts, functional features, stress analysis, ease of assembly, serviceability, and manufacturability are refined for the most promising solutions.)

D. Model or prototype analysis

(NOTE: In this stage the design is analyzed, studied, and refined to prove that the design works. This is a very important step that may cause you to return to one of the other steps.)

E. Presentation/working drawings

(NOTE: This stage is the formal documented form for production which includes detail drawings, assembly drawings, and parts lists. The primary focus is to sell the idea or product to others.)

VI. Design layouts (Transparency 6)

A. Drawn by the designer as part of the design process

B. Amount of detail needed depends on the degree of competency of the drafter

1. Requires very little detail if the drafter is well trained

2. Requires a great deal of detail if the drafter is not well trained

C. May include the following:

(NOTE: The following items represent the maximum detail a designer would place on a design layout.)

INFORMATION SHEET

1. Accurate to-scale details of each part
2. Strength calculations
3. Function calculations
4. Cost calculations
5. Weight calculations
6. Shape or form determinations
7. Stress analysis
8. Explanation of how parts fit together
9. Most dimensions
10. Notes for standard parts or special processes
11. Clearances for moving parts
12. Ease of assembly
13. Ease of serviceability
14. Standard parts recommended wherever possible
15. Special manufacturing problems

D. Drawn accurately with thin lines

E. Usually only critical dimensions are included

VII. Basic elements of a design layout sketch (Transparency 6)

(NOTE: Many drawings do not need to be drawn accurately to prove they work. A designer or engineer may simply make a sketch of his/her needs and the drafter can make a detail drawing.)

A. Projection (multiview, isometric)

B. Line symbols and darkness

C. Proportions

D. Strength calculations

E. Function calculations

F. Cost calculations

G. Weight calculations

INFORMATION SHEET

H. Shape or form determinations

I. Stress analysis

J. Way parts fit together

K. All critical dimensions

L. Notes for standard parts or special processes

M. Clearances for moving parts

N. Ease of assembly

O. Ease of serviceability

P. Standard parts recommended wherever possible

Q. Special manufacturing problems

VIII. Standard parts of a detail drawing (Transparency 7)

A. Shape description

(NOTE: This includes multiview, auxiliary, sections, and/or pictorials.)

B. Dimensions

(NOTE: These include size, location, and tolerances.)

C. Notes

(NOTE: These may be general or specific.)

IX. Parts of an assembly drawing and functions (Transparency 8)

A. Views--Show relationship of parts

(NOTE: Views do not show the shapes of individual parts but just how they fit together.)

B. Sections--Show the inside function or construction of the parts

C. Hidden lines--Shown only to promote clearness; unnecessary when several sections are used

(NOTE: Hidden lines may not be necessary and in some cases would only confuse the reading of the drawing.)

INFORMATION SHEET

D. Dimensions--Show maximum or minimum sizes or locations of machine parts after assembly and overall size

(NOTE: Only certain dimensions and notes are given on an assembly drawing.)

E. Parts identification numbers--Allow for quick identification of physical shape and guide reader to the parts list (Figure 1)

(NOTE: An identification number should be 5mm high in a 12mm circle. The circle is connected to the part with an arrowhead, dot, or S.)

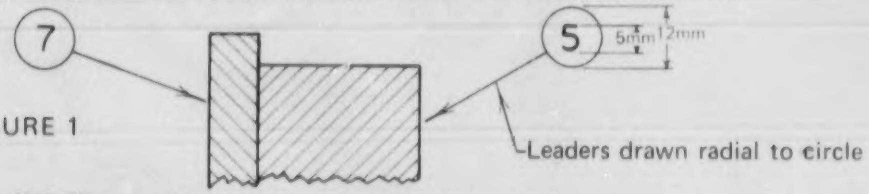


FIGURE 1

Leaders drawn radial to circle

(NOTE: Avoid vertical and horizontal leaders.)

X. Information found on outline or installation assemblies (Transparency 10)

A. Method for installing or erecting a machine or structure

B. Outline and relationships of external surfaces

C. Relationship of final positioning for subassemblies

XI. Information found on welding assembly drawings (Transparency 11)

A. Parts identification

B. Dimensioning

(NOTE: This includes the detailed or after-welded final dimensions. Proper jigs must be used to prevent distortion to maintain final dimensions.)

C. Standard welding symbols (ANSI Y 32.3-1969)

D. Parts list

(NOTE: Parts may be made from stock.)

E. Multiviews and auxiliary views, if used

(NOTE: Sections are not normally employed in welding assembly drawings.)

XII. Characteristics of forging drawings (ANSI Y14.9-1958) (Transparency 12)

A. Fillets and rounds--Minimum sizes (Figure 2)

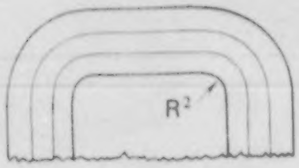
INFORMATION SHEET

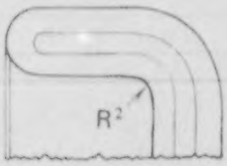
B. Parting line--Separation of upper and lower dies

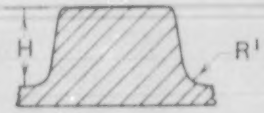
C. Draft--Ease in removal from dies

D. Extra material not needed in final product

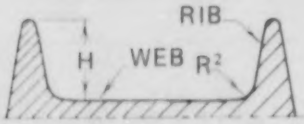
FIGURE 2



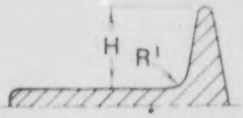




Boss



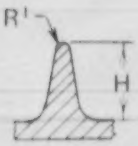
Opposing Ribs--
Confined Metal in Web



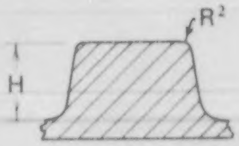
Single Rib

H	R^1	R^2
1/4	1/8	1/8
1/2	1/8	1/8
1	1/4	3/8
2	1/2	5/8
3	3/4	1
4	1	1 3/8
5	1 1/4	1 3/4
6	1 1/2	2

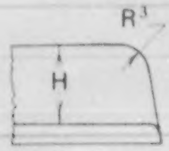
FILLET RADII



Rib



Boss



End of Rib

H	R^1	R^2	R^3
1/4	1/16	1/16	3/16
1/2	1/16	1/16	3/16
1	1/8	1/8	3/8
2	3/16	1/4	1/2
3	1/4	5/16	3/4
4	5/16	7/16	1
5	3/8	1/2	1 1/8
6	7/16	5/8	1 1/4
7	1/2	11/16	1 1/2

CORNER RADII

XIII. Information found on a pattern or casting drawing (Transparency 13)

A. Fillets and rounds--Minimum sizes

B. Parting line--Separation of one mold from the other

C. Extra material not needed in final product

(NOTE: A draft may be included by the pattern maker, but it is not shown on the drawing.)

MD - 175

Engineering Change Notice

NO.		AN
DATE ISSUED	CONT. ON SHEET	SHEET NO.

APPARATUS:

SERIES AN NO ☐ YES ☐ FINAL ☐

AR NO.

REQ

ENG. PROD. PLAN AFFECTED ☐ NOT AFFECTED ☐

PREVIOUS SERIES AN:

CLASS OF CHG. - 1 EMERGENCY - 2 MEET SPEC. 3 EXC'D SPEC. - 4 NEW MODEL

IT.	NAME OF PART	DWG. NO.	REV	UNITS AFFECTED	SERIAL NOS.

REASON FOR CHANGE/PROBLEM

SUMMARY OF CHANGE/SOLUTION

STATUS OF MATERIAL:

TMBS		MDBS		RTBS	

SERIAL NUMBERS TO BE REWORKED

PROGRAMMING AFFECTED NO ☐ YES ☐

DIAGNOSTICS AFFECTED NO ☐ YES ☐ PGMS.

PRODUCT SERVICE INFORMATION

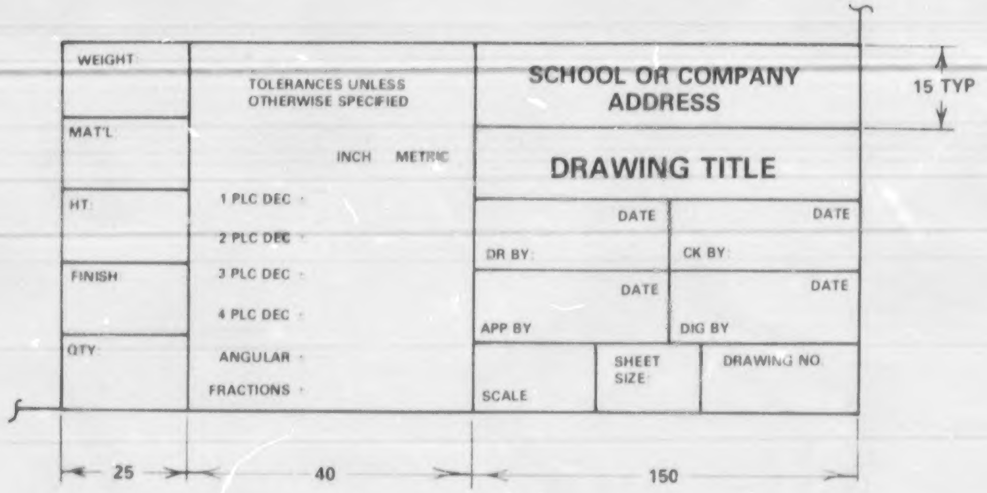
DOCUMENTATION IS AFFECTED ☐ NOT AFFECTED ☐

EQUIP. CHANGE IS MANDATORY ☐ NOT AFFECTED ☐

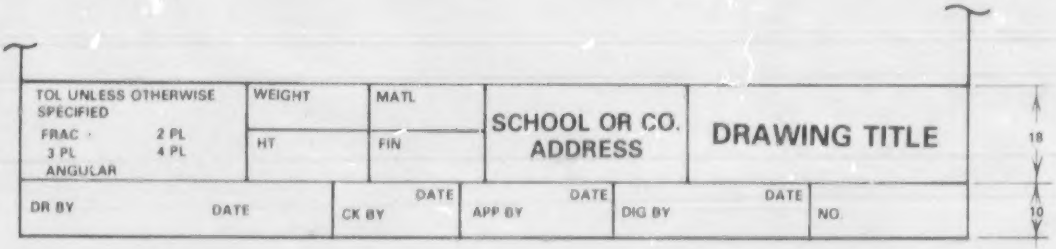
SPARE PARTS ARE AFFECTED ☐ NOT AFFECTED ☐

ISSUED BY:	DATE:	APPROVALS:	DIST. KEY		
APPROVED BY:	DATE:				

Title Forms


WEIGHT
MAT'L
HT
FINISH
QTY
TOLERANCES UNLESS OTHERWISE SPECIFIED
INCH
METRIC
1 PLC DEC
2 PLC DEC
3 PLC DEC
4 PLC DEC
ANGULAR
FRACTIONS
SCHOOL OR COMPANY ADDRESS
DRAWING TITLE
DATE
DR BY
DATE
CK BY
DATE
APP BY
DATE
DIG BY
SCALE
SHEET SIZE
DRAWING NO
15 TYP
25
40
150

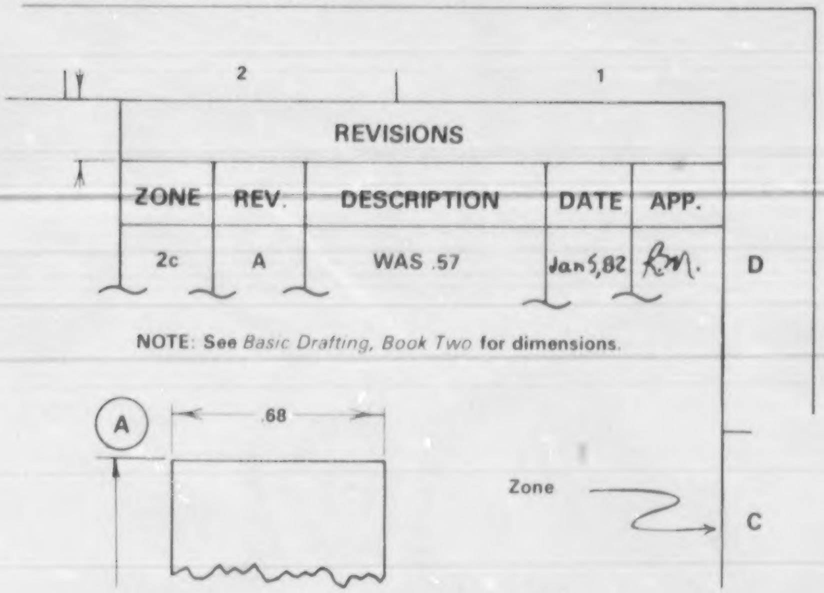
Title Block


TOL UNLESS OTHERWISE SPECIFIED
FRAC
2 PL
3 PL
4 PL
ANGULAR
WEIGHT
MATL
HT
FIN
SCHOOL OR CO. ADDRESS
DRAWING TITLE
DR BY
DATE
DATE
CK BY
DATE
APP BY
DATE
DIG BY
NO
18
10

Title Strip

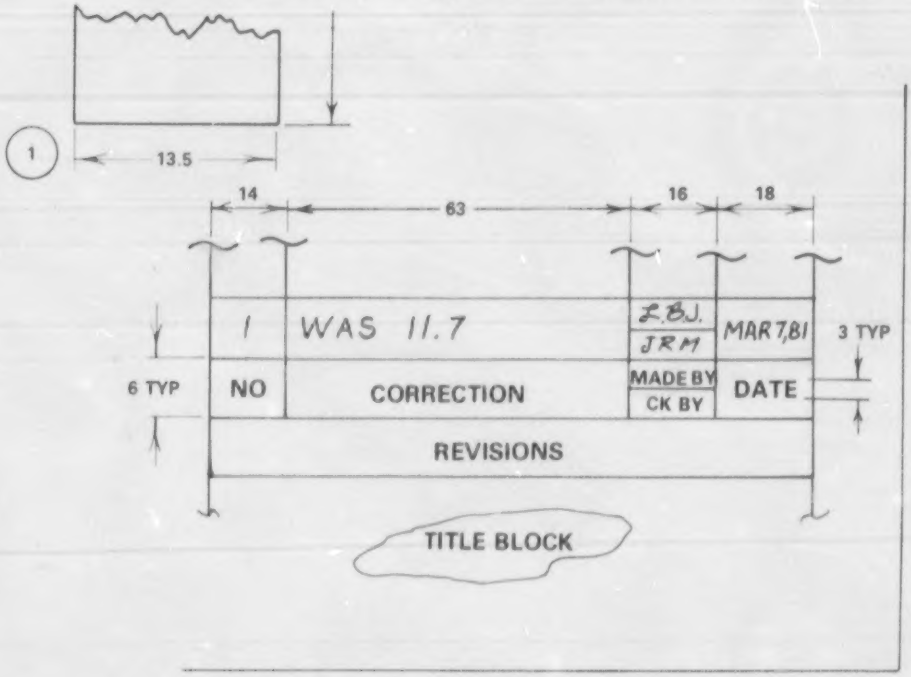
(NOTE: All lettering is 3mm high except Title and Drawing numbers which are 6mm high.)

Revisions


2
1
REVISIONS
ZONE
REV.
DESCRIPTION
DATE
APP.
2c
A
WAS .57
Jan 5,82
D
A
.68
Zone
C

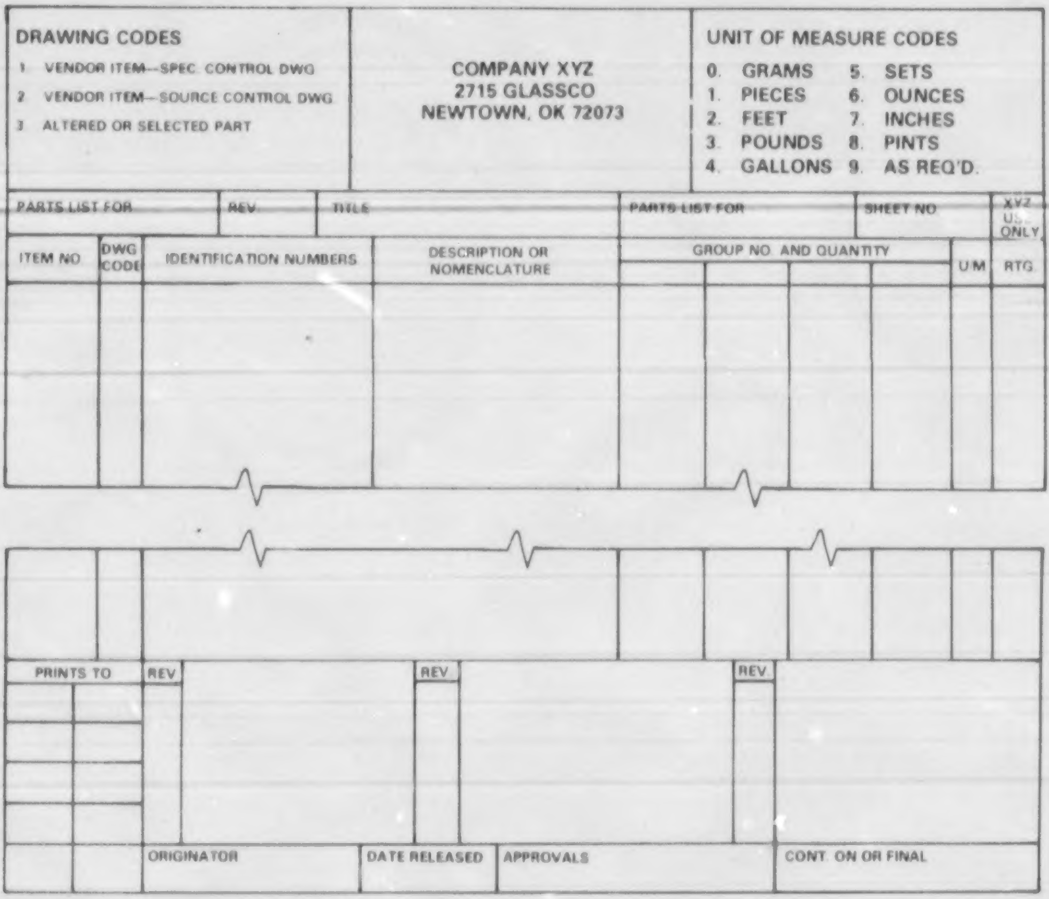
NOTE: See *Basic Drafting, Book Two* for dimensions.

Revision Form With Zones


1
13.5
14
63
16
18
1
WAS 11.7
L.B.J.
JRM
MAR 7,81
3 TYP
6 TYP
NO
CORRECTION
MADE BY
CK BY
DATE
REVISIONS
TITLE BLOCK

Revision Form Without Zones

Bill of Materials / Parts List



DRAWING CODES

1 VENDOR ITEM--SPEC. CONTROL DWG
2 VENDOR ITEM--SOURCE CONTROL DWG
3 ALTERED OR SELECTED PART

COMPANY XYZ
2715 GLASSCO
NEWTOWN, OK 72073

UNIT OF MEASURE CODES

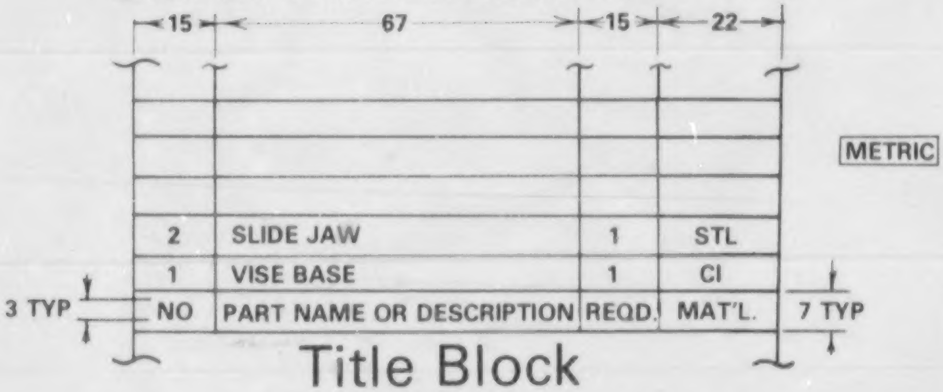
0. GRAMS	5. SETS
1. PIECES	6. OUNCES
2. FEET	7. INCHES
3. POUNDS	8. PINTS
4. GALLONS	9. AS REQ'D.

PARTS LIST FOR	REV.	TITLE	PARTS LIST FOR	SHEET NO	XYZ USE ONLY

ITEM NO	DWG CODE	IDENTIFICATION NUMBERS	DESCRIPTION OR NOMENCLATURE	GROUP NO. AND QUANTITY				U/M	RTG.

PRINTS TO
REV
REV
REV
ORIGINATOR
DATE RELEASED
APPROVALS
CONT. ON OR FINAL

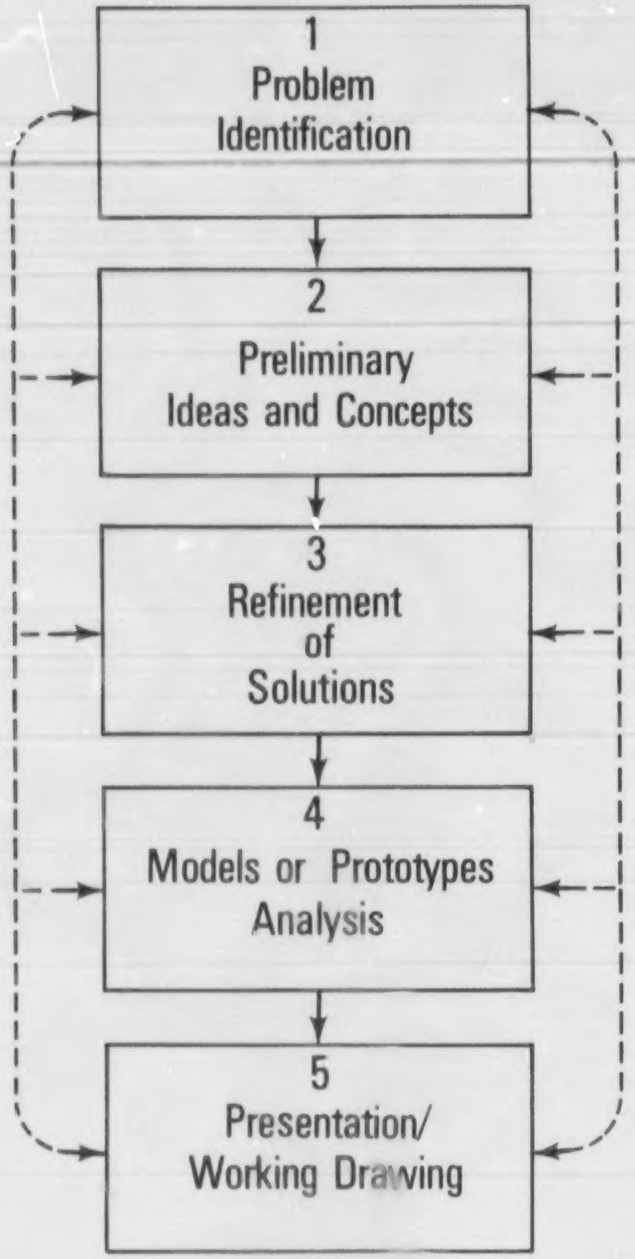
Bill of Materials/Parts List



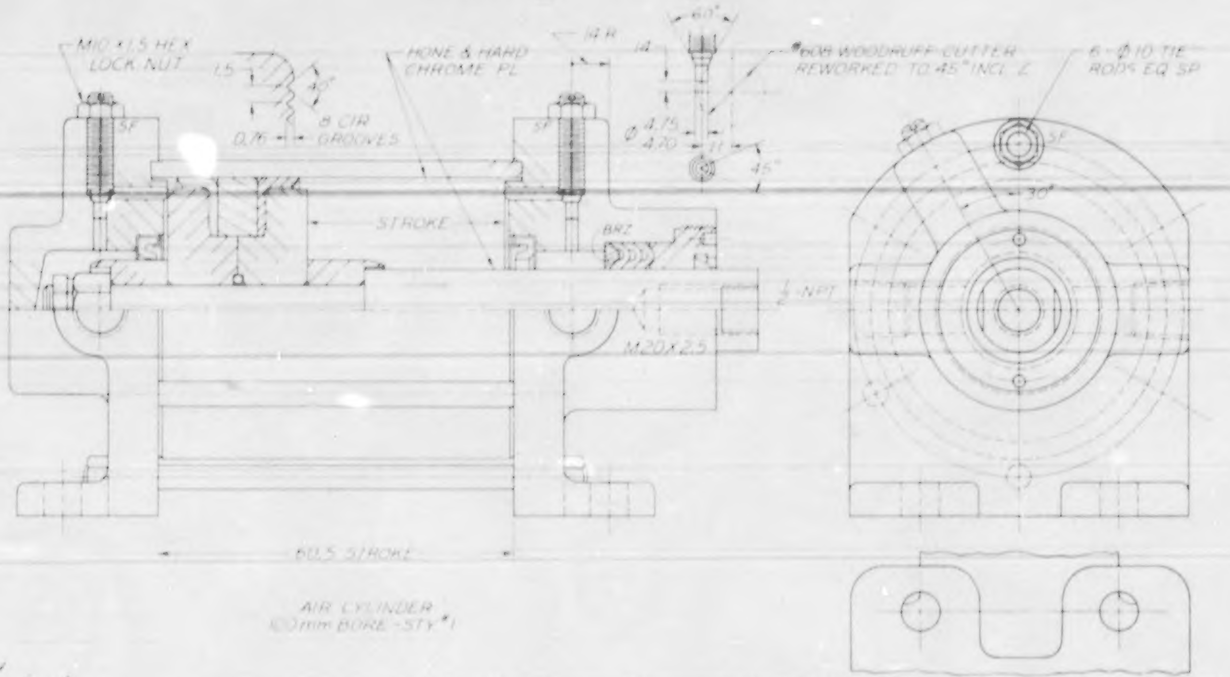
2	SLIDE JAW	1	STL
1	VISE BASE	1	CI
NO	PART NAME OR DESCRIPTION	REQD.	MAT'L.

Parts List--Short Form Over Title Block

Design Process


1
Problem Identification
2
Preliminary Ideas and Concepts
3
Refinement of Solutions
4
Models or Prototypes Analysis
5
Presentation/ Working Drawing

Design Layout


M10 X 1.5 HEX LOCK NUT
HONE & HARD CHROME PL
14 R
14
60°
#608 WOODRUFF CUTTER REWORKED TO 45° INCL ∠
6 - Ø10 TIE RODS EQ SP
1.5
40°
0.76
8 CIR GROOVES
SF
Ø 4.75 4.70
11
45°
STROKE
BRZ
½ NPT
M20 X 2.5
30°
60.5 STROKE
AIR CYLINDER 100mm BORE - STY #1

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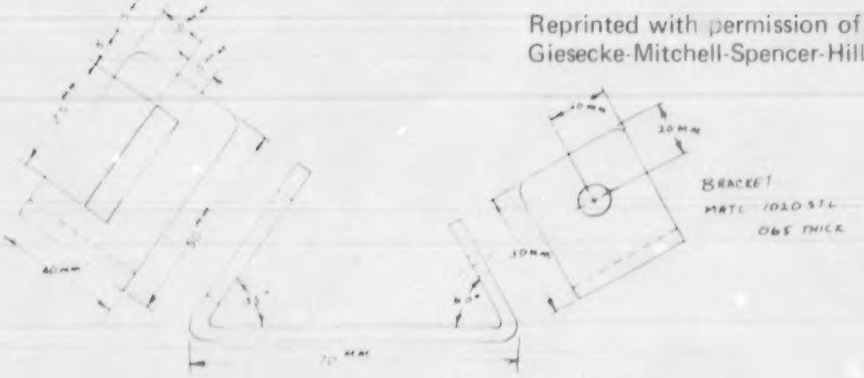
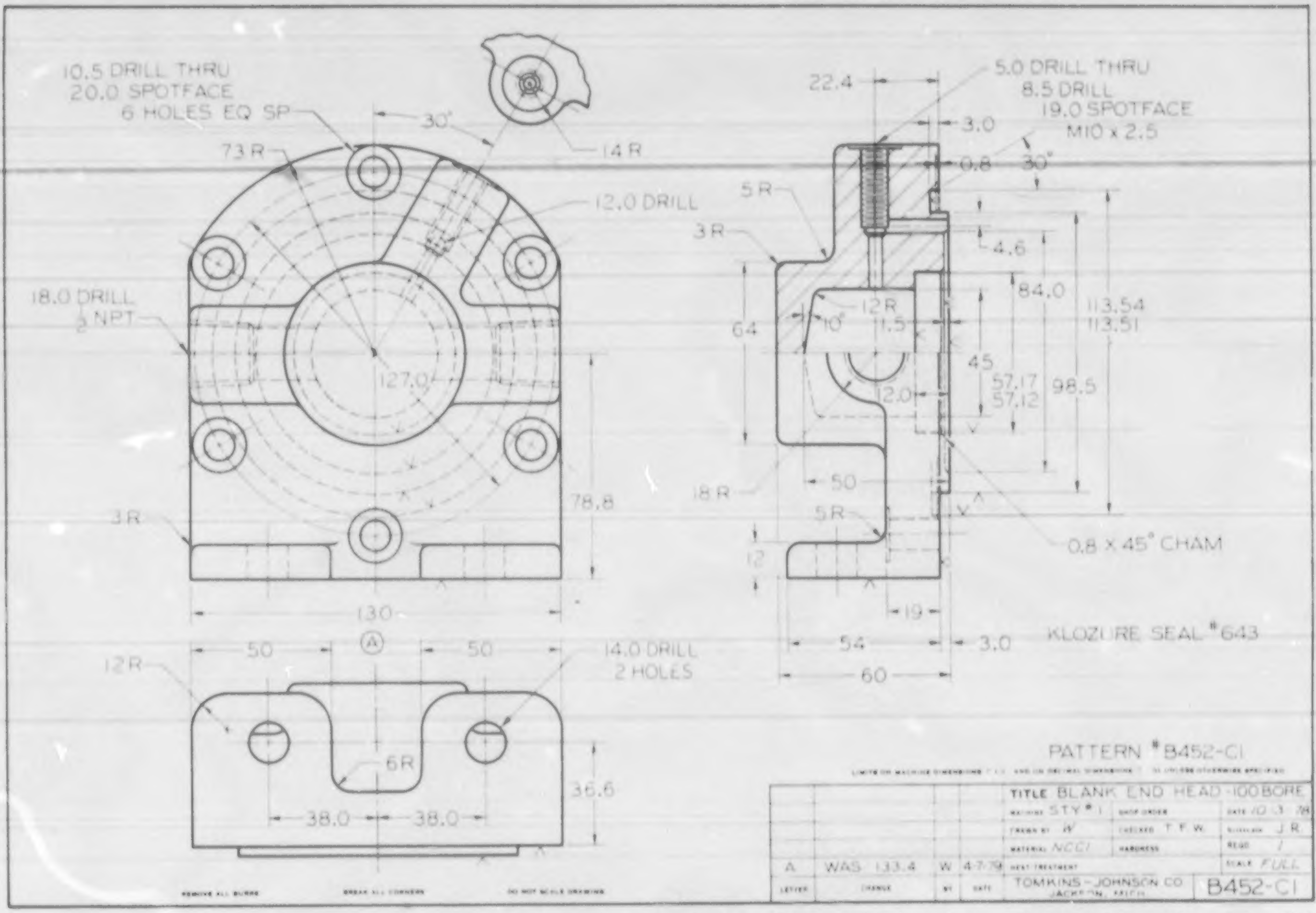

40mm
20mm
30mm
70mm
60°
BRACKET
MAT'L 1020 STL
065 THICK

Design Layout

Freehand Sketch

Detail Drawing


10.5 DRILL THRU
20.0 SPOTFACE
6 HOLES EQ SP
30°
14 R
73 R
12.0 DRILL
18.0 DRILL
1/2 NPT
127.0
3 R
78.8
130
(A)
12 R
50
50
14.0 DRILL
2 HOLES
6R
38.0
38.0
36.6
22.4
5.0 DRILL THRU
8.5 DRILL
19.0 SPOTFACE
M10 x 2.5
3.0
0.8
30°
5 R
3 R
4.6
84.0
113.54
113.51
12 R
10°
1.5
64
45
57.17
57.12
98.5
12.0
18 R
50
5 R
0.8 X 45° CHAM
12
19
54
3.0
60
KLOZURE SEAL #643
PATTERN #B452-CI
TITLE BLANK END HEAD -100 BORE
STY # 1
SHOP ORDER
DATE 10-3-78
W
CHECKED T. F. W.
J. R.
MATERIAL NCCI
HARDNESS
REQD 1
HEAT TREATMENT
SCALE FULL
A
WAS 133.4
W
4-7-79
LETTER
CHANGE
BY
DATE
TOMKINS-JOHNSON CO
JACKSON, MICH.
B452-CI
REMOVE ALL BURRS
BREAK ALL CORNERS
DO NOT SCALE DRAWING

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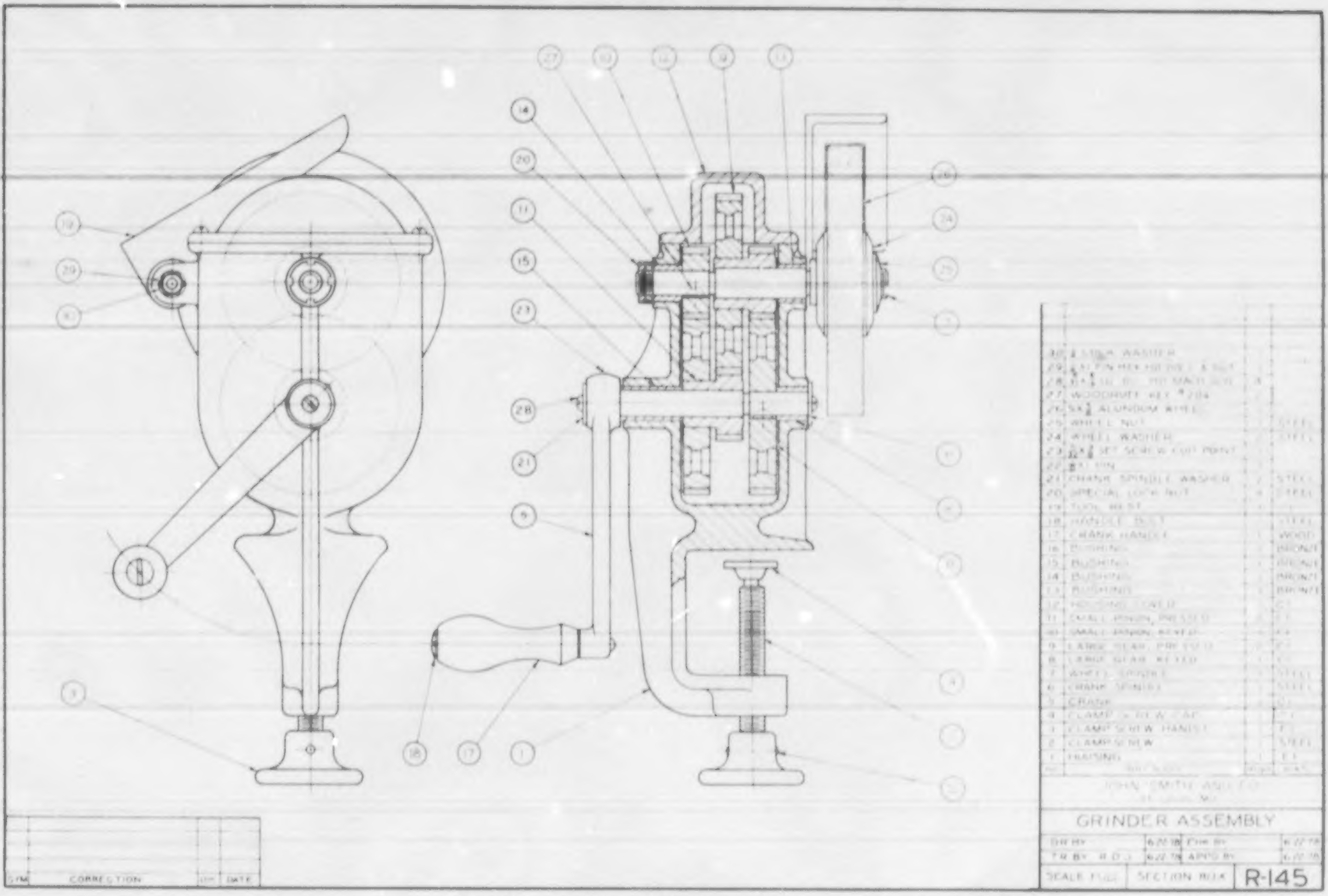
Assembly Drawing



27
10
12
9
13
14
20
11
15
23
28
21
5
19
29
6
3
18
17
1
26
24
25
30 ¼ STD. WASHER
29 ¼ x 1 ⅞ HEX HD BOLT & NUT
28 No. 6 x ½ FIL HD MACH SCR
27 WOODRUFF KEY #204
26 5 x ⅝ ALUNDUM WHEEL
25 WHEEL NUT 1 STEEL
24 WHEEL WASHER 2 STEEL
23 SET SCREW CUP POINT
22 PIN
21 CRANK SPINDLE WASHER 2 STEEL
20 SPECIAL LOCK NUT 4 STEEL
19 TOOL REST
18 HANDLE BOLT STEEL
17 CRANK HANDLE 1 WOOD
16 BUSHING BRONZE
15 BUSHING BRONZE
14 BUSHING BRONZE
13 BUSHING BRONZE
12 HOUSING COVER CI
11 SMALL PINION, PRESSED CI
10 SMALL PINION, KEYED CI
9 LARGE GEAR, PRESSED CI
8 LARGE GEAR, KEYED CI
7 WHEEL SPINDLE STEEL
6 CRANK SPINDLE STEEL
5 CRANK CI
4 CLAMP SCREW CAP CI
3 CLAMP SCREW HANDLE CI
2 CLAMP SCREW STEEL
1 HOUSING 1 CI
NO. PART NAME REQD MAT.
JOHN SMITH AND CO.
GRINDER ASSEMBLY
DR BY 6/22/78 CHK BY 6/22/78
TR BY R.D.J. 6/22/78 APP'D BY 6/22/78
SCALE FULL
SECTION R.D.K.
R-145
SYM CORRECTION BY DATE

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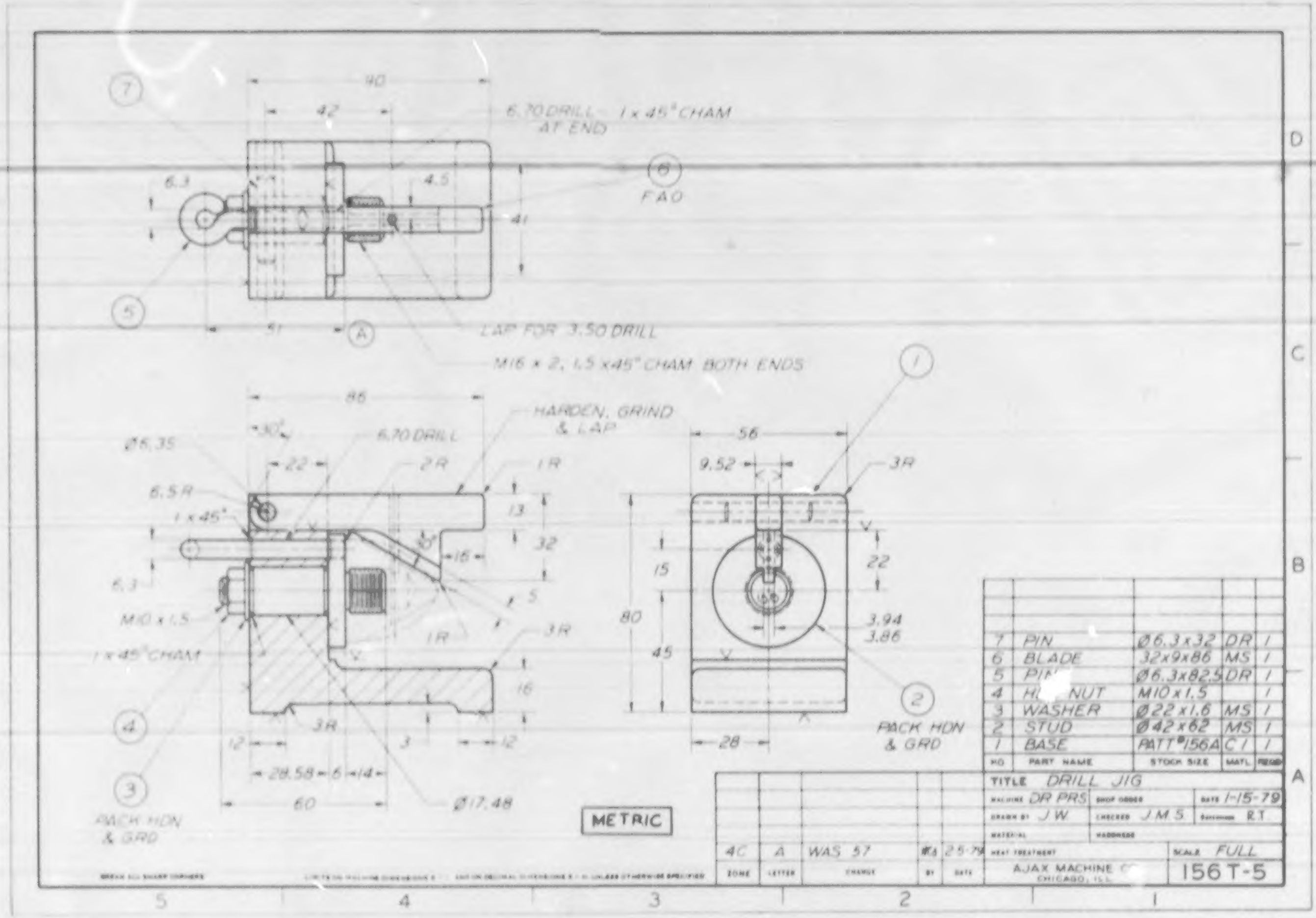
Detail Assembly Drawing


90
42
6.70 DRILL
AT END
1 x 45° CHAM
6.3
4.5
41
⑥
FAO
⑦
⑤
51
Ⓐ
LAP FOR 3.50 DRILL
M16 x 2, 1.5 x 45° CHAM BOTH ENDS
①
86
30°
6.70 DRILL
HARDEN, GRIND
& LAP
Ø6.35
22
2R
1R
6.5R
1 x 45°
13
32
30°
16
6.3
5
M10 x 1.5
1R
3R
1 x 45° CHAM
16
3R
3
12
12
28.58
6
14
60
Ø17.48
④
③
PACK HDN
& GRD
56
9.52
3R
15
22
80
45
3.94
3.86
28
②
PACK HDN
& GRD
METRIC
7 PIN Ø6.3 x 32 DR 1
6 BLADE 32 x 9 x 86 MS 1
5 PIN Ø6.3 x 82.5 DR 1
4 HEX NUT M10 x 1.5 1
3 WASHER Ø22 x 1.6 MS 1
2 STUD Ø42 x 62 MS 1
1 BASE PATT #156A C I 1
NO PART NAME STOCK SIZE MATL REQD
TITLE DRILL JIG
MACHINE DR PRS
SHOP ORDER
DATE 1-15-79
DRAWN BY J.W.
CHECKED J.M.S.
APPROVED R.T.
MATERIAL
HARDNESS
HEAT TREATMENT
SCALE FULL
4C A WAS 57 2-5-79
ZONE LETTER CHANGE BY DATE
AJAX MACHINE CO.
CHICAGO, ILL.
156 T-5
D
C
B
A
5
4
3
2
1

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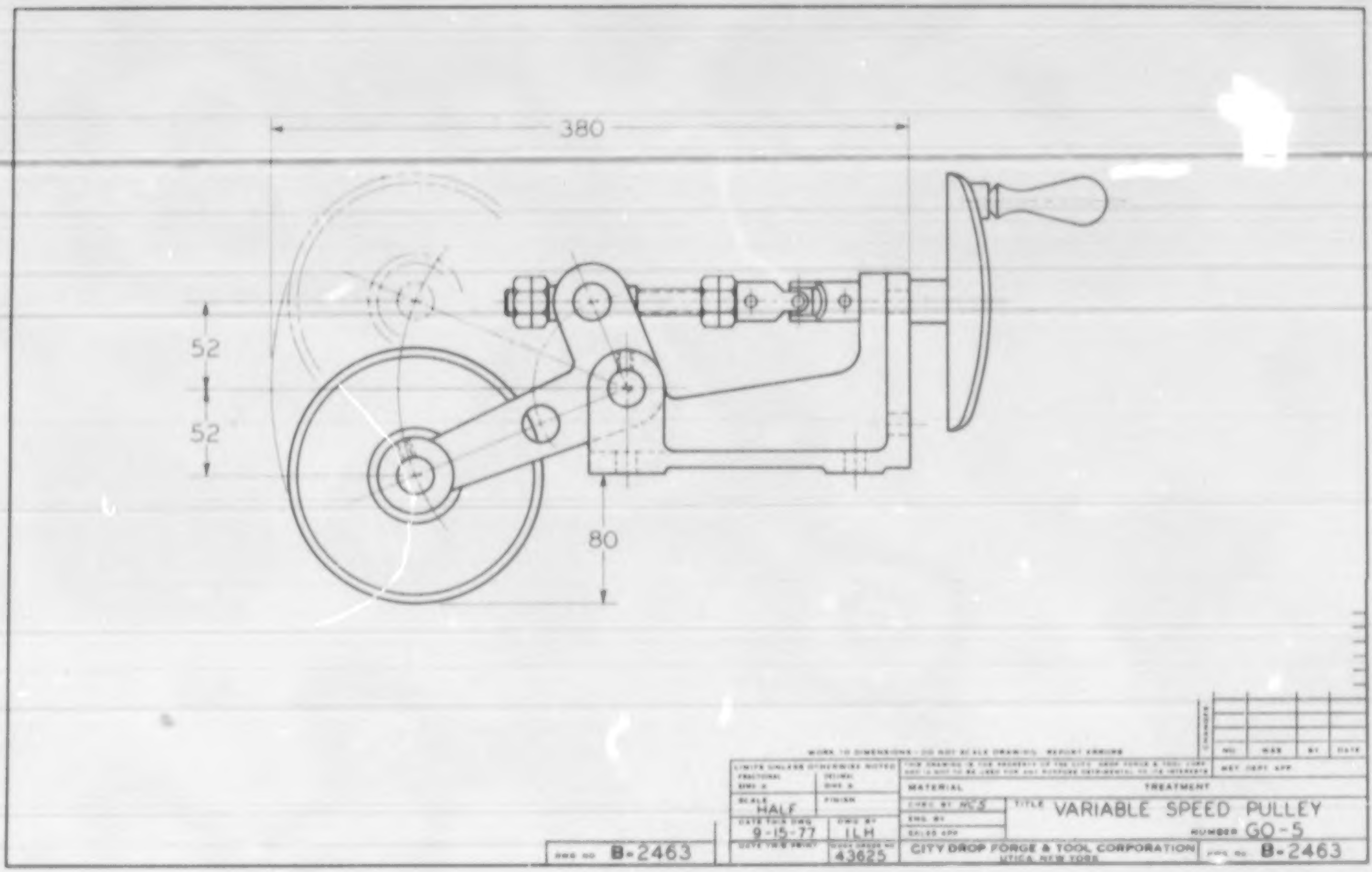
Outline or Installation Assembly


380
52
52
80
MATERIAL
TREATMENT
SCALE HALF
FINISH
CHKD BY HCS
ENG BY
DATE THIS DWG 9-15-77
DWG BY ILH
43625
TITLE VARIABLE SPEED PULLEY
NUMBER GO-5
CITY DROP FORGE & TOOL CORPORATION
UTICA NEW YORK
B-2463
B-2463
NO
WAS
BY
DATE

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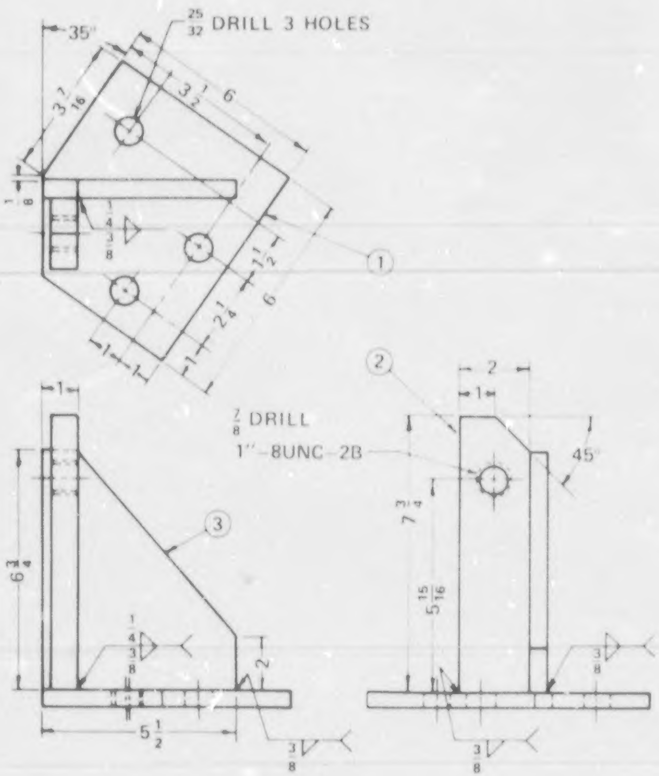
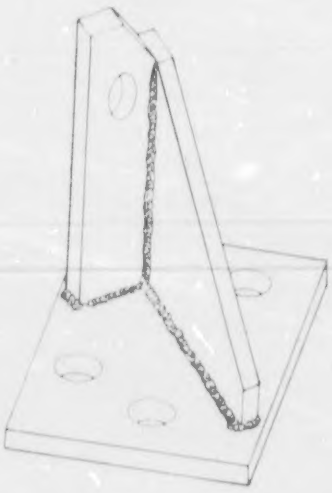
Welding Assembly Drawing

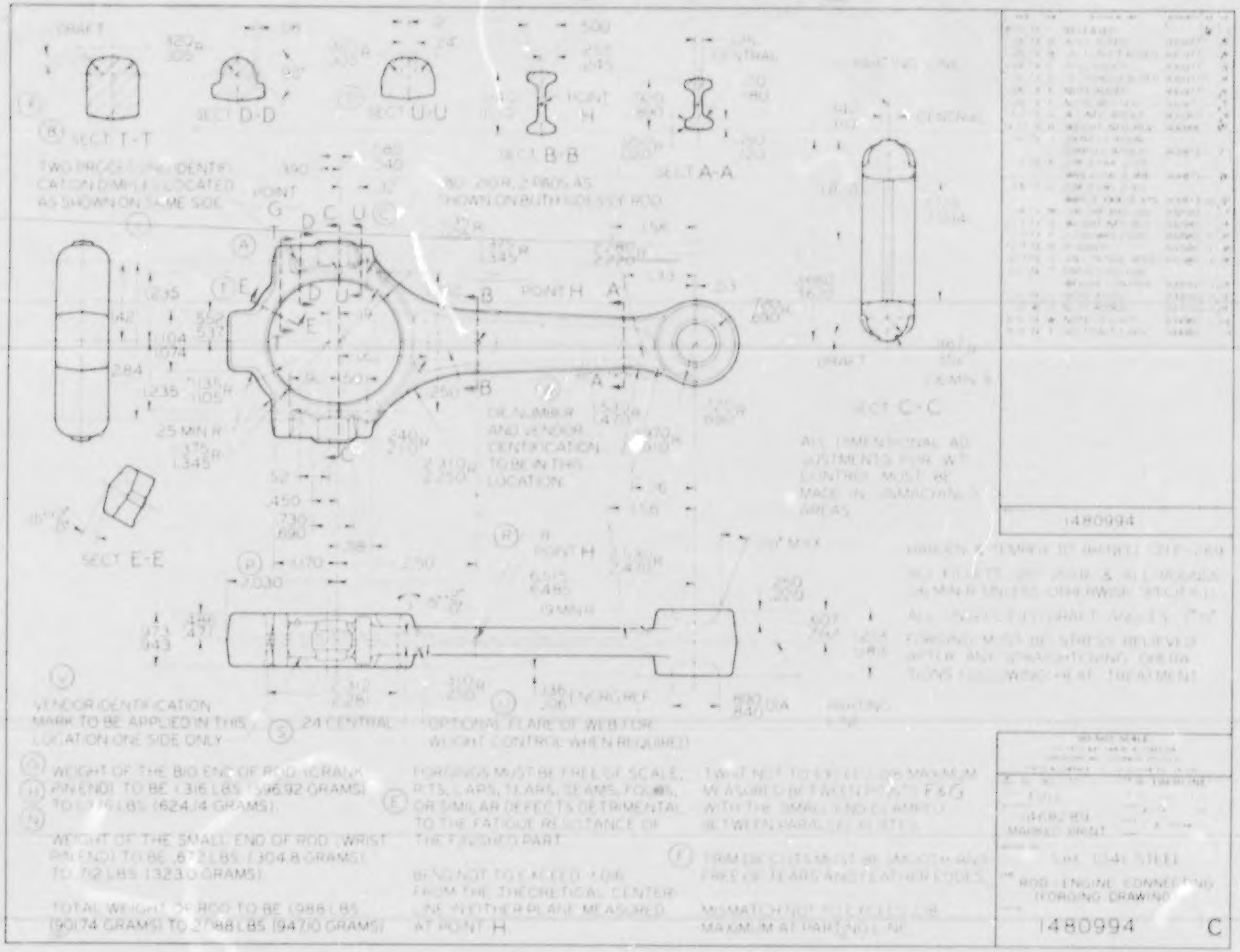

35°
25/32 DRILL 3 HOLES
3 7/16
3 1/2
6
1/8
1/4
3/8
1 1/2
6
2 1/4
1
1
①
1
7/8 DRILL
1"–8UNC–2B
②
2
1
45°
7 3/4
5 15/16
6 1/4
③
1/4
3/8
2
5 1/2
3/8
3/8
3/8



3	1	5½ x ½ Plate 6¾ long	1020
2	1	2 x ¾ Bar - 7¾ long	1020
1	1	6 x ½ Plate - 6 long	1020
NO	REQD	DESCRIPTION	QTY

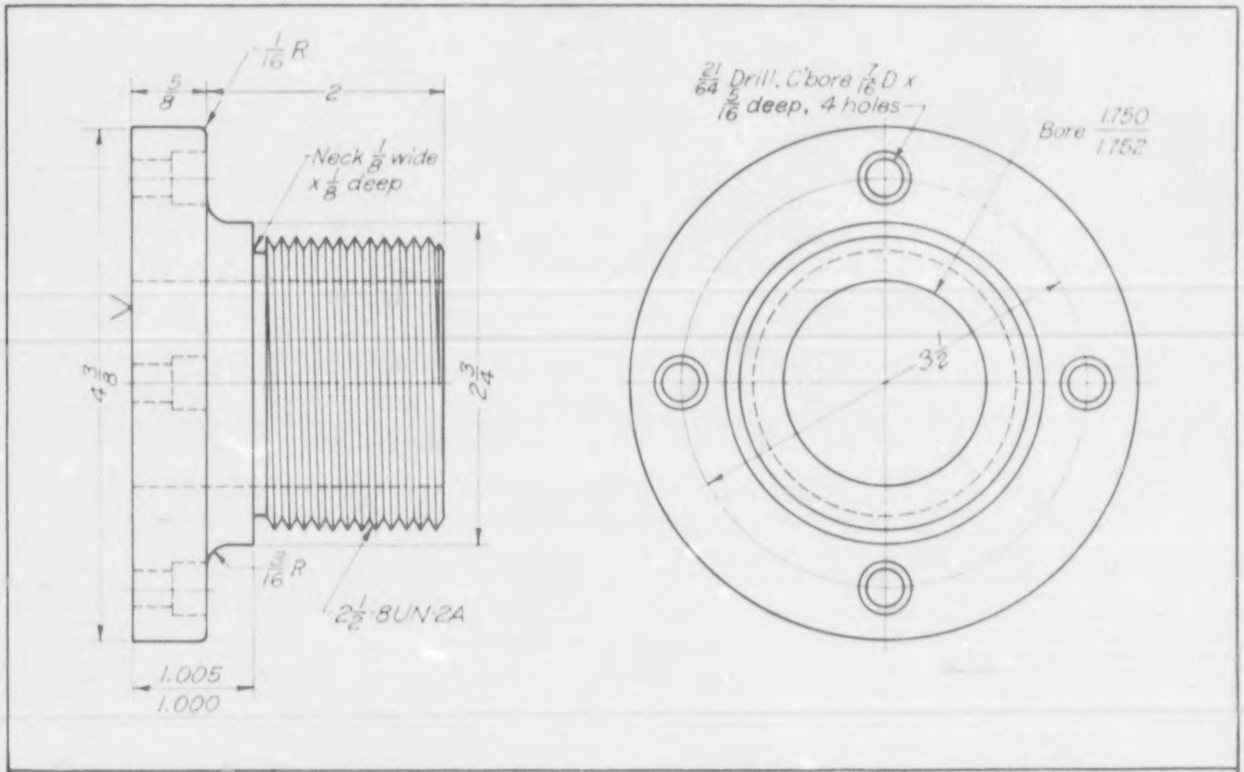
Farm Machines Inc.		
Date	Approved By	Dr By
Scale 1:5		Ck By
Bracket Assembly		15B625

Forging Drawing


SECT T-T
SECT D-D
SECT U-U
SECT B-B
SECT A-A
SECT C-C
SECT E-E
POINT G
POINT H
DRAFT
1480994
ROD - ENGINE CONNECTING (FORGING DRAWING)
1480994
C

Reprinted with permission of the publisher from *Technical Drawing.* 7th edition, by Giesecke-Mitchell-Spencer-Hill-Dygdon, Macmillan Publishing Co., Inc., 1980.

Casting Drawing


$\frac{1}{16}$ R
$\frac{5}{8}$
2
Neck $\frac{1}{8}$ wide x $\frac{1}{8}$ deep
$4\frac{3}{8}$
$2\frac{3}{4}$
$\frac{3}{16}$ R
$2\frac{1}{2}$-8UN-2A
1.005
1.000
$\frac{21}{64}$ Drill, C'bore $\frac{7}{16}$ D x $\frac{5}{16}$ deep, 4 holes
Bore $\frac{1.750}{1.752}$
$3\frac{1}{2}$

DWN	C.H.L.	7-9-81
TCD	JONES	7-15-81
CKD	H.J.J.	7-21-81
APPD	J. Smith.	7-29-81
	NAME	DATE

LIMITS UNLESS OTHERWISE NOTED:
FRACTIONAL $\pm\frac{1}{64}$, DECIMAL $\pm$.010, ANGULAR $\pm\frac{1}{2}^\circ$

PART NO	REQD	NAME
107	2	HOUSING SUPPORT
UNIT OR ASSEMBLY	No. 7 SCREENER	

REVISION	DATE	CHANGE OR ADDITION		
MATERIAL	STOCK SIZE		HEAT TR	FINISH
C.I.				As Shown
SCALE	COMPANY NAME CITY			DRAWING NO.
Full				NO OF
ASSY DR NO				74238
74200				

From *Engineering Drawing and Graphic Technology* by French and Vierck, 1978. Used with the permission of McGraw-Hill Book Company.

LAYOUTS AND WORKING DRAWINGS
UNIT IV

ASSIGNMENT SHEET #1–DRAW A DESIGN LAYOUT

Directions: For the project assigned by your instructor, sketch the desired layout to include standard parts and fixed dimensions. Tape drawing media to drawing surface, and draw your design layout. Letter in information in its proper place using correct lettering techniques.

LAYOUTS AND WORKING DRAWINGS
UNIT IV

ASSIGNMENT SHEET #2–DRAW A SET OF DETAIL DRAWINGS

Directions: Using the design layout of the project from Assignment Sheet #1, sketch each detail to include proper placement of dimensions, tolerances, and notes. Tape drawing media to drawing surface, and draw each detail on a *separate* sheet of paper of appropriate size. Letter in information in its proper place using correct lettering techniques.

LAYOUTS AND WORKING DRAWINGS
UNIT IV

ASSIGNMENT SHEET #3–DRAW AN ASSEMBLY DRAWING

Directions: For this assignment use details from either Assignment Sheet #2, the design layout of Assignment Sheet #1, or a different project appropriate to time. Sketch an assembly drawing to include appropriate sections, views, and dimensions. Tape drawing media to drawing surface, and draw an assembly drawing. Letter in information in its proper place using correct lettering techniques.

LAYOUTS AND WORKING DRAWINGS
UNIT IV

ASSIGNMENT SHEET #4–COMPLETE A DETAILED TITLE BLOCK AND REVISION BLOCK

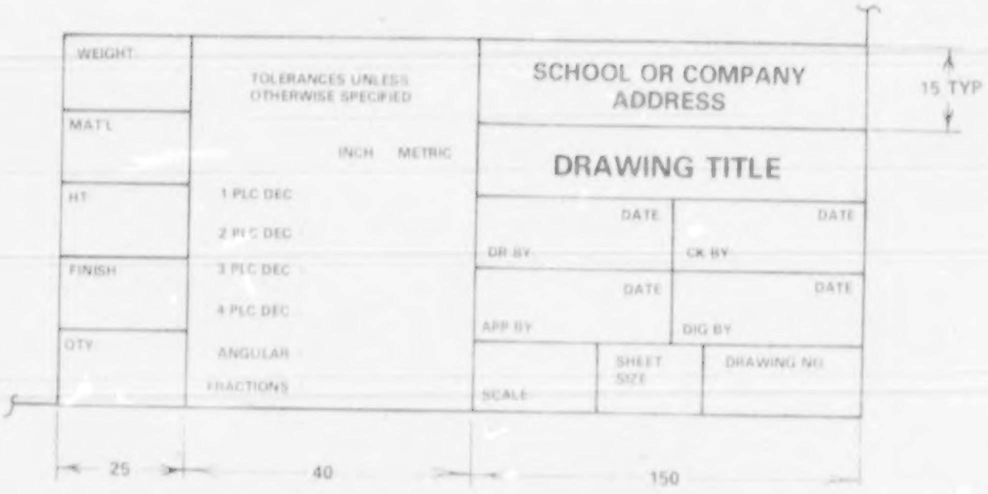
Directions: With a lettering guide and the drawing media from Assignment Sheet #2 and #3, use the procedure in the following example to complete a detailed title block and revision block.

Example:

1. Tape drawing media to drawing surface
2. Select correct pencils
3. Select appropriate title block for detail information

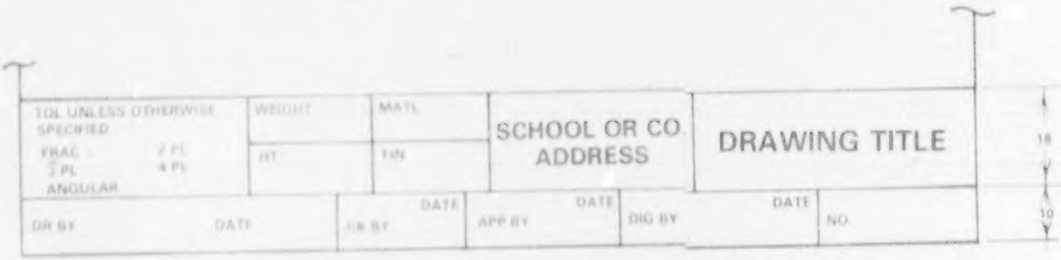
   (NOTE: Refer to the following examples of title strips and title blocks. Select one shown or devise one of your own which has been approved by the instructor.)

Example:


WEIGHT
MAT'L
HT
FINISH
QTY
TOLERANCES UNLESS OTHERWISE SPECIFIED
INCH
METRIC
1 PLC DEC
2 PLC DEC
3 PLC DEC
4 PLC DEC
ANGULAR
FRACTIONS
SCHOOL OR COMPANY ADDRESS
DRAWING TITLE
DATE
DR BY
DATE
CK BY
DATE
APP BY
DATE
DIG BY
SCALE
SHEET SIZE
DRAWING NO.
15 TYP
25
40
150

(NOTE: This title block can be used with "C," "D," and "E" size sheets.)

ASSIGNMENT SHEET #4


TOL UNLESS OTHERWISE SPECIFIED
FRAC ±
2 PL
3 PL
4 PL
ANGULAR
WEIGHT
MATL
HT
FIN
SCHOOL OR CO. ADDRESS
DRAWING TITLE
DR BY
DATE
CK BY
DATE
APP BY
DATE
DIG BY
DATE
NO.
18
10

(NOTE: This title block can be used with "A" and "B" size sheets.)

4. Draw title block in lower right hand corner
5. Draw guidelines for lettering
6. Letter in information in its proper place using correct lettering techniques
7. Select revision block containing zone reference
8. Draw revision block in upper right hand corner
9. Letter in information in its proper place using correct lettering techniques

LAYOUTS AND WORKING DRAWINGS
UNIT IV

ASSIGNMENT SHEET #5--COMPLETE A PARTS LIST

Directions: Tape either the drawing from Assignment Sheet #3 or a separate parts list (PL) form on drawing surface. Draw a parts list. Letter in information in the parts list using correct lettering techniques.

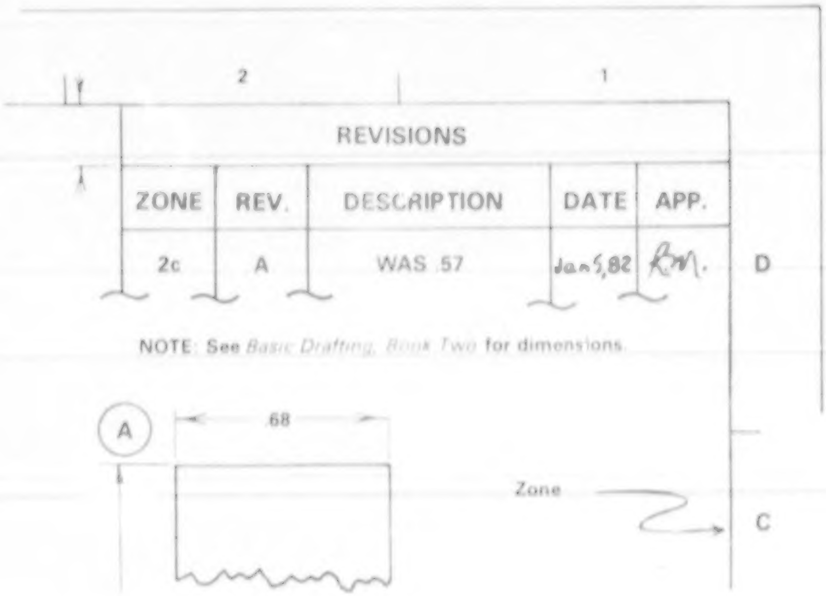
LAYOUTS AND WORKING DRAWINGS
UNIT IV

ASSIGNMENT SHEET #6–MAKE A DRAWING REVISION

Directions: In order to make a drawing revision, you will need the drawings from Assignment Sheets #2, #3, and #4 and an Engineering Change Notice (ECN) from your instructor. Now use the procedure in the following example to make the revision.

Example:

1. Letter revision on drawing
2. Letter revision in revision block
3. Sign and date revision block
4. Make a blueline print of revision
5. Turn in revision and print to instructor



REVISIONS				
ZONE	REV.	DESCRIPTION	DATE	APP.
2c	A	WAS .57	Jan 5,82	R.M.

NOTE: See *Basic Drafting, Book Two* for dimensions.

LAYOUTS AND WORKING DRAWINGS
UNIT IV

NAME________________________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. Change made on a drawing

_____b. Equal intervals along the margins labeled with numbers along the horizonal margin and with letters along the vertical margin for locating an area on a drawing

_____c. Drawing containing the necessary information to completely manufacture a single part or one stage of a single part

_____d. Name of the object or project

_____e. Area to show all information related to a drawing revision

_____f. Organized method to combine scientific principles, standard parts and resources into the solution of a problem

_____g. Drawing showing all parts in their working position

_____h. Standardized place to show all information not shown with notes and dimensions on the drawing

_____i. Combined detail and assembly drawing used when the details are simple enough for all parts to be shown and dimensioned clearly while shown in assembled positions

_____j. Accurate drawing of all parts in working positions showing clearances of moving parts, ease of assembly, and ease of serviceability

_____k. Itemized list of parts shown with an assembly drawing

_____l. A detail drawing of a workpiece to be cast

1. Title
2. Title form
3. Revision
4. Engineering change notice
5. Revision form
6. Zoning
7. Bill of materials/ parts list
8. Casting drawing
9. Design layout
10. Design process
11. Detail drawing
12. Assembly drawing
13. Forging drawing
14. Detail assembly drawing

_____m. A detail drawing of a workpiece to be forged in dies

_____n. An approved change to a drawing caused by a change in design, tool changes, errors in design or production, and customer changes

2. Distinguish between standard and additional information on a title form by placing an "X" next to the standard information and an "O" next to the additional information.

_____a. Tolerances

_____b. Revision letter

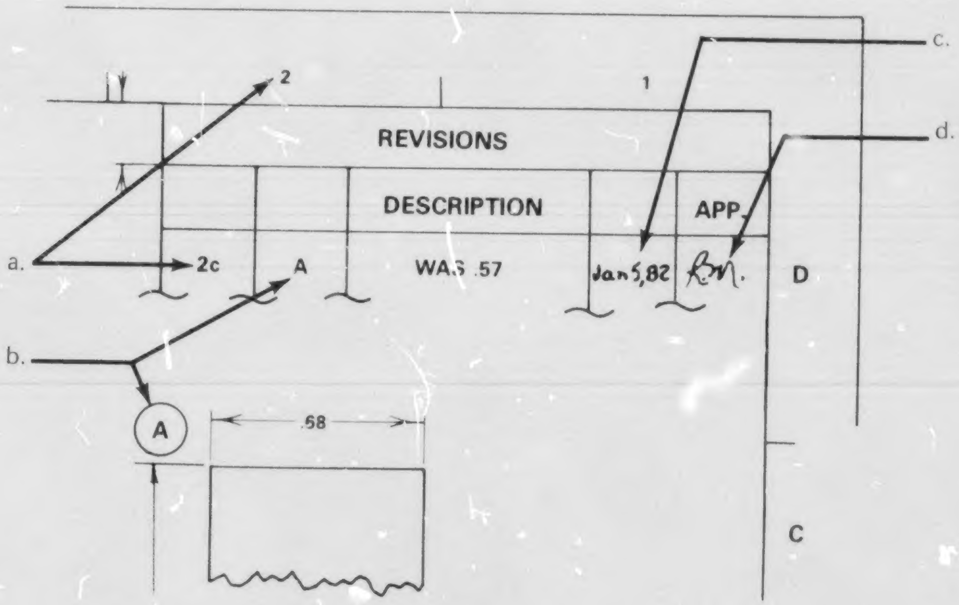
_____c. Signature of drafter with date of completion

_____d. Hardness

_____e. Heat treatment

_____f. Predominate scale of drawing

3. Identify information on a revision block.



a. ______________________ b. ______________________

c. ______________________ d. ______________________

4. List information on a bill of materials/parts list.

   a. Standard information

      1) ______________________________

      2) ______________________________

   b. Additional information

      1) ______________________________

      2) ______________________________

      3) ______________________________

      4) ______________________________

5. Arrange in order the following stages of the design process by placing the correct sequence numbers in the appropriate blanks.

   _____a. Refinement of solutions

   _____b. Presentation/working drawings

   _____c. Problem identification

   _____d. Model or prototype analysis

   _____e. Preliminary ideas and concepts

6. Select true statements concerning design layouts by placing an "X" in the appropriate blanks.

   _____a. Drawn by the designer as part of the design process

   _____b. Requires a great deal of detail if the drafter is well trained

   _____c. May include strength calculations

   _____d. May include weight calculations

   _____e. Drawn with thick lines

   _____f. All dimensions are omitted

   _____g. May include clearances for moving parts

   _____h. May include ease of serviceability

7. List eight basic elements of a design layout sketch.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

g. ______________________________

h. ______________________________

8. Name the three standard parts of a detail drawing.

a. ______________________________

b. ______________________________

c. ______________________________

9. Match the parts of an assembly drawing on the right with the correct functions.

______a. Shown only to promote clearness; unnecessary when several sections are used

______b. Allow for quick identification of physical shape and guide reader to the parts list

______c. Show maximum or minimum sizes or locations of machine parts after assembly and overall size

______d. Show relationship of parts

______e. Show the inside function or construction of the parts

1. Views
2. Sections
3. Hidden lines
4. Dimensions
5. Parts identification numbers

10. Select information found on outline or installation assemblies by placing an "X" in the appropriate blanks.

______a. Method for installing or erecting a machine or structure

______b. Sections of internal detail of a machine

______c. Outline and relationships of external surfaces

______d. Detail dimensions of individual parts

______e. Relationship of final positioning for subassemblies

11. Select information found on welding assembly drawings by placing an "X" in the appropriate blanks.

    _____a. Parts identification

    _____b. Dimensioning

    _____c. Standard welding symbols

    _____d. Parts list

    _____e. Sections

    _____f. Auxiliary views, if used

12. Select characteristics of forging drawings by placing an "X" in the appropriate blanks.

    _____a. Fillets and rounds

    _____b. Finish marks

    _____c. Drilled holes

    _____d. Parting line

    _____e. Draft

    _____f. Extra material not needed in final product

13. Select information found on a pattern or casting drawing by placing an "X" in the appropriate blanks.

    _____a. Fillets and rounds

    _____b. Finish marks

    _____c. Drilled holes

    _____d. Parting line

    _____e. Draft

    _____f. Extra material not needed in final product

14. Demonstrate the ability to:

    a. Draw a design layout.

    b. Draw a set of detail drawings.

    c. Draw an assembly drawing.

    d. Complete a detailed title block and revision block.

    e. Complete a parts list.

    f. Make a drawing revision.

    (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

LAYOUTS AND WORKING DRAWINGS
UNIT IV

ANSWERS TO TEST

1. a. 3
   b. 6
   c. 11
   d. 1
   e. 5
   f. 10
   g. 12
   h. 2
   i. 14
   j. 9
   k. 7
   l. 8
   m. 13
   n. 4

2. a. O
   b. X
   c. X
   d. O
   e. O
   f. X

3. a. Zone for location of change
   b. Letter of change
   c. Date of change
   d. Person checking change (approved by)

4. a. Any two of the following:
   1) Item number referring to assembly drawing
   2) Part name
   3) Number required
   4) Material from which part is made

   b. Any four of the following:
   1) Stock number
   2) Description or nomenclature
   3) Address of vender
   4) Unit of measure
   5) Group subassembly where used
   6) Approval
   7) Release date
   8) Originator
   9) Revision
   10) Stock size
   11) Pattern number
   12) Weight

5. a. 3
   b. 5
   c. 1
   d. 4
   e. 2

6. a, c, d, g, h

7. Any eight of the following:
    a. Projection
    b. Line symbols and darkness
    c. Proportions
    d. Strength calculations
    e. Function calculations
    f. Cost calculations
    g. Weight calculations
    h. Shape or form determinations
    i. Stress analysis
    j. Way parts fit together
    k. All critical dimensions
    l Notes for standard parts or special processes
    m. Clearances for moving parts
    n. Ease of assembly
    o. Ease of serviceabilty
    p. Standard parts recommended wherever possible
    q. Special manufacturing problems

8. a. Shape description
    b. Dimensions
    c. Notes

9. a. 3
    b. 5
    c. 4
    d. 1
    e. 2

10. a, c, e

11. a, b, c, d, f

12. a. d, e, f

13. a, d, f

14. Evaluated to the satisfaction of the instructor

DIMENSIONING AND TOLERANCING
UNIT V

UNIT OBJECTIVE

After completion of this unit, the student should be able to illustrate dimensioning tolerances to include surface quality, position and geometric form dimensions. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment sheets and by scoring 85 percent on the unit test.

(NOTE: Students are expected to review "Dimensioning Procedures" and "Basic Tolerancing" of *Basic Drafting, Book Two* before attempting this unit.)

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to dimensioning and tolerancing with the correct definitions.
2. Distinguish between size and location dimensions for a geometric shape.
3. Select mating dimensions in an assembly drawing.
4. Select true statements concerning numerical control dimensioning.
5. Distinguish between fits for inch units and fits for metric units.
6. Calculate limits in inch units using basic hole system.
7. Calculate limits in inch units using basic shaft system.
8. Calculate limits in metric units using basic hole system.
9. Determine the tolerance ranges for shop processes using the accompanying table.
10. Distinguish between clearance fit and interference fit of hole size limits for standard dowels.
11. Select true statements concerning limit dimensions for interchangeability of parts.
12. Arrange in order the steps for determining limit dimensions for intermediate parts to retain overall limits.
13. Complete a chart of characteristic symbols for tolerances of position and form.
14. Match terms with the correct supplementary symbols for tolerances of position and form.

15. Match position and form symbols with the correct descriptions.

16. Match the descriptions of position and form with the correct meaning of drawings.

17. Select true statements concerning positional tolerancing.

18. Distinguish between maximum material condition and regardless of feature size.

19. Select true statements concerning angular tolerances.

20. State the purpose of surface quality specifications.

21. Identify parts of a surface quality symbol.

22. Select true statements concerning surface quality notes.

23. Match lay symbols with the correct designations.

24. Differentiate between correct and incorrect placement of surface quality symbols.

25. Select true statements concerning surface roughness produced by common production methods using the accompanying table.

26. Select preferred recommended roughness, waviness, and roughness width cutoff values from tables.

27. Demonstrate the ability to:

    a. Dimension an object completely.

    b. Calculate and dimension clearance fit tolerances using standard fit tables.

    c. Calculate and dimension interference fit tolerances using standard fit tables.

    d. Calculate and assign tolerances to mating parts using standard fit tables.

    e. Calculate and dimension hole size limits for standard dowels.

    f. Dimension an object using position and form tolerances.

    g. Determine ranges of motion of limbs and spaces required for a person.

DIMENSIONING AND TOLERANCING
UNIT V

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and assignment sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Develop a display of different types of gages with corresponding parts to be measured for size and location.

VII. Have students check a group of parts for correct dimensions by using gages.

VIII. Provide part drawings for students to see specified tolerances.

IX. Visit a manufacturing quality control department to see how they operate and inspect parts.

X. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
  A. Objective sheet
  B. Information sheet
  C. Transparency masters
    1. TM 1--Tolerancing Terms
      1A--Overlay
      1B--Overlay
    2. TM 2--Graphical Representation of Tolerance Zones (Metric)
    3. TM 3--Metric Tolerance Designation
    4. TM 4--Determining Limits for Hole and Shaft (Inch Units)
    5. TM 5--Determining Limits for Hole and Shaft (Metric Units)
    6. TM 6--Tolerances Related to Shop Processes

7. TM 7--Hole Size for Standard Dowel (Fit Dimensions)

   7A--Overlay

8. TM 8--Interchangeability of Mating Parts (Problem)
9. TM 9--Interchangeability of Mating Parts (Calculations)
10. TM 10 and Overlay 10A--Limits for Intermediate Parts
11. TM 11--Symbols for Tolerances of Position and Form
12. TM 12--Use of Symbols for Tolerances of Position and Form
13. TM 13--Application of Symbols to Position and Form Tolerance Dimensions
14. TM 14--No Specified Tolerance of Form
15. TM 15--Straightness
16. TM 16--Flatness
17. TM 17--Roundness
18. TM 18--Cylindricity
19. TM 19--Profile of a Surface
20. TM 20--Profile of a Surface Between Points
21. TM 21--Angularity of a Plane Surface
22. TM 22--Perpendicularity
23. TM 23--Perpendicularity (Continued)
24. TM 24--Parallelism
25. TM 25--Concentricity
26. TM 26--Symmetry
27. TM 27--Positional Tolerancing
28. TM 28--Tolerance Zones
29. TM 29--Cylindrical Tolerance Zones
30. TM 30--No Tolerance Accumulation
31. TM 31--Maximum and Least Material Conditions
32. TM 32--Regardless of Feature Size
33. TM 33--Angular Tolerances

34. TM 34--Surface Quality Symbol

35. TM 35--Lay Symbols

D. Assignment sheets

1. Assignment Sheet #1--Dimension an Object Completely

2. Assignment Sheet #2--Calculate and Dimension Clearance Fit Tolerances Using Standard Fit Tables

3. Assignment Sheet #3--Calculate and Dimension Interference Fit Tolerances Using Standard Fit Tables

4. Assignment Sheet #4--Calculate and Assign Tolerances to Mating Parts Using Standard Fit Tables

5. Assignment Sheet #5--Calculate and Dimension Hole Size Limits for Standard Dowels

6. Assignment Sheet #6--Dimension an Object Using Position and Form Tolerances

7. Assignment Sheet #7--Determine Ranges of Motion of Limbs and the Spaces Required for a Person

E. Answers to assignment sheets

F. Test

G. Answers to test

II. References:

A. Giesecke, Frederick E., et al. *Technical Drawing*. New York 10022: Macmillan Publishing Co., Inc. 1980.

B. Levens, Alexander and William Chalk. *Graphics in Engineering Design*. New York: John Wiley and Sons, 1980.

C. Dent, Joseph B., et al. *Fundamentals of Engineering Graphics*. 51st edition, Macmillan Publishing Co., Inc., 1979.

D. Jensen, Cecil and Jay Helsel. *Engineering Drawing and Design*. New York: Gregg Division/McGraw-Hill Book Company, 1979.

E. American National Standards Institute. *Dimensioning and Tolerancing*. (ANSI Y14.5-1973). New York 10017: American Society of Mechanical Engineers, 1973.

F. Foster, Lowell W. *Geo-Metrics*. Reading, MA: Addison-Wesley, 1974.

G. Dreyfuss, Henry. *The Measure of Man: Human Factors in Design*. 2nd ed. New York: Whitney Library of Design, 1967.

DIMENSIONING AND TOLERANCING
UNIT V

INFORMATION SHEET

I. Terms and definitions (Transparencies 1, 2, and 3)

   A. Interchangeability--The condition that refers to a part made to limit dimensions so that it will fit any part similarly manufactured; the ability of mating parts to fit properly together

   B. Geometric shapes--Shapes such as prisms, cylinders, pyramids, cones, and spheres

   C. Size dimension--Any type of dimension that tells how large or small an object is

   D. Location dimension--Any type of dimension that locates a feature on an object

   E. Tolerance--The total amount of variation permitted in limit dimensioning of a part; the difference between the limit dimensions (Transparency 1)

   F. Basic size--The size of a part determined by engineering and design requirements from which the limits of size are determined; the line of zero deviation

   G. Limits--The extreme permissible dimensions of a part resulting from the application of a tolerance; the maximum and minimum size indicated by a tolerance

   H. Maximum material condition (MMC)--Used when maximum material is present in a feature

      (NOTE: This is the smallest hole, largest shaft.)

   I. Least material condition (LMC)--Used when the least material is present in a feature

      (NOTE: This is the largest hole, smallest shaft.)

   J. Upper deviation--Difference between the maximum limit and the basic size

   K. Lower deviation--Difference between the minimum limit and the basic size

   L. International tolerance grade--Group of tolerances numbered 01 - 16

      (NOTE: 01 thru 5 are used for gages, 6 thru 12 are used for fits, and 13 thru 16 are used for general dimensioning.)

   M. Fundamental deviation--The deviation nearer the basic size for the hole and near the basic size for the shaft

      (NOTE: The fundamental deviation is an upper case letter for holes and a lower case letter for shafts.)

INFORMATION SHEET

N. Tolerance zone--The association of a fundamental deviation (letter) with an international tolerance grade (IT number)

O. Basic hole system--The basic size of the hole is the design size (basic size) and the allowance is applied to the shaft

(NOTE: The fundamental deviation for a hole system is H.)

P. Basic shaft system--The basic size of the shaft is the design size and the allowance is applied to the hole

(NOTE: The fundamental deviation for a shaft system is h.)

Q. Clearance fit--Limits of size are determined so that a loose fit or positive allowance occurs between mating parts

R. Interference fit--Limits of size are determined so that a negative allowance or tight fit occurs between mating parts

S. Transition fit--Limits of size are determined so that the allowance may be either a clearance fit or an interference fit

T. Allowance--The minimum international difference in the dimensions of mating parts to provide for different classes of fits; the minimum clearance or maximum interference when parts are at maximum material condition (MMC)

U. Datums--Points, lines, or other geometric shapes assumed to be exact from which the location or geometric form of features of a part may be established

V. Positional tolerance--Exact theoretical position of a feature established by basic dimensions

(NOTE: The term "positional tolerancing" has the same meaning as "true position tolerancing.")

W. Form tolerances--Maximum allowable variations of a perfect geometric shape

X. Surface quality--Roughness, waviness, and lay of a surface which may include certain flaws

Y. Lay--Direction of the major surface pattern determined by manufacturing method used

Z. Roughness--Fine irregularities in surface texture

AA. Waviness--Widely spaced element of a surface texture

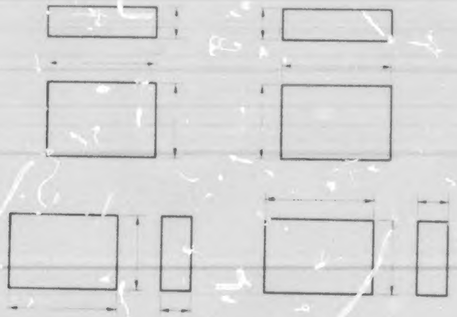
BB. Anthropometric data--Measurements of the human body and its parts

INFORMATION SHEET

II. Size and location dimensions for geometric shapes

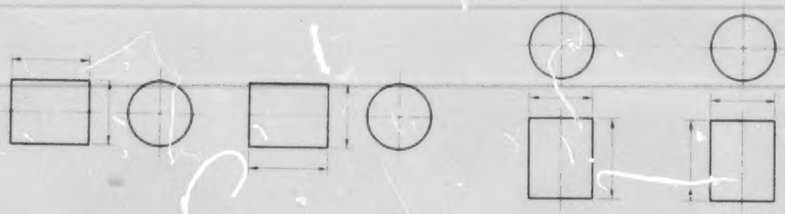
A. Size dimensions

1. Prisms

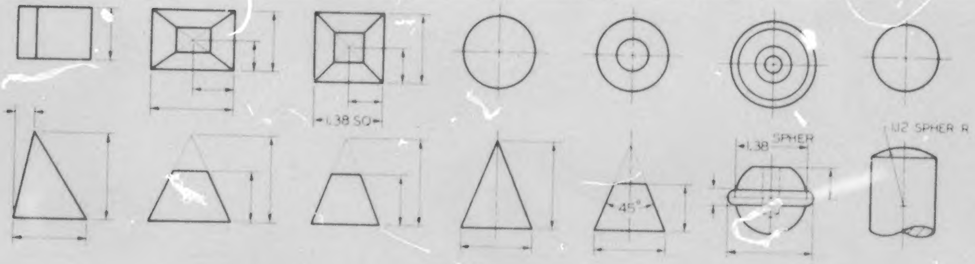


2. Cylinders

(NOTE: Diameter is not recommended for circular view but ANSI does approve its use.)



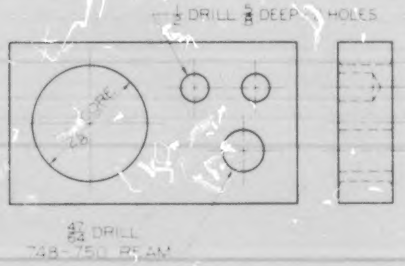
3. Miscellaneous shapes

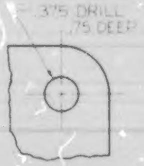

1.38 SQ
1.38 SPHER
45°
1.12 SPHER R

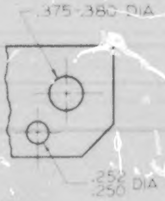
INFORMATION SHEET

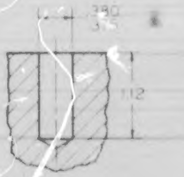
4. Holes (negative cylinders)

(NOTE: These may be drilled, reamed, bored, punched, or cored specified by standard notes.)


$\frac{1}{2}$ DRILL $\frac{5}{8}$ DEEP 2 HOLES
2.8 CORE
$\frac{47}{64}$ DRILL
.748–.750 REAM

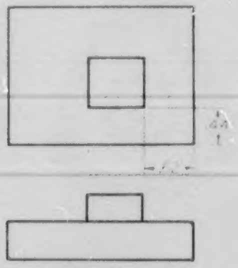

.375 DRILL
.75 DEEP


.375–.380 DIA
.252
.250 DIA



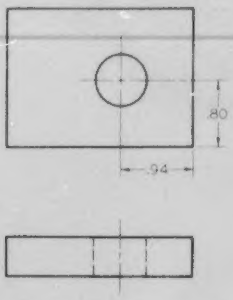
B. Location dimensions

1. Rectangular shapes--Reference to their faces



2. Cylinders or holes--Reference to their center lines

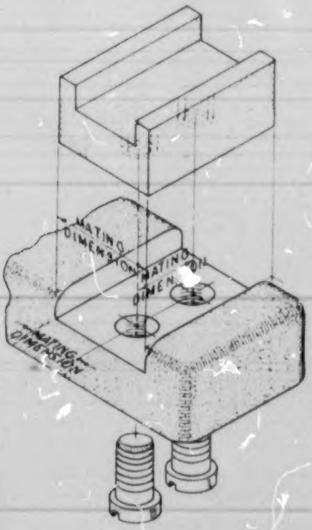
(NOTE: Location dimensions are best located in circular view.)

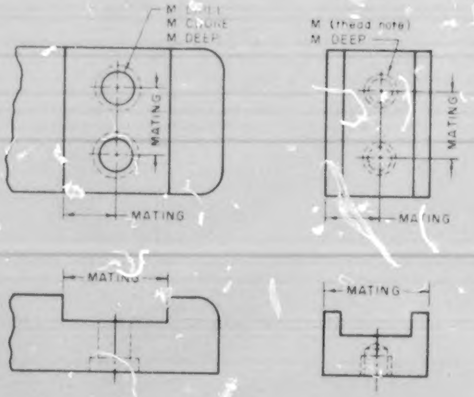


INFORMATION SHEET

III. Mating dimensions in an assembly drawing

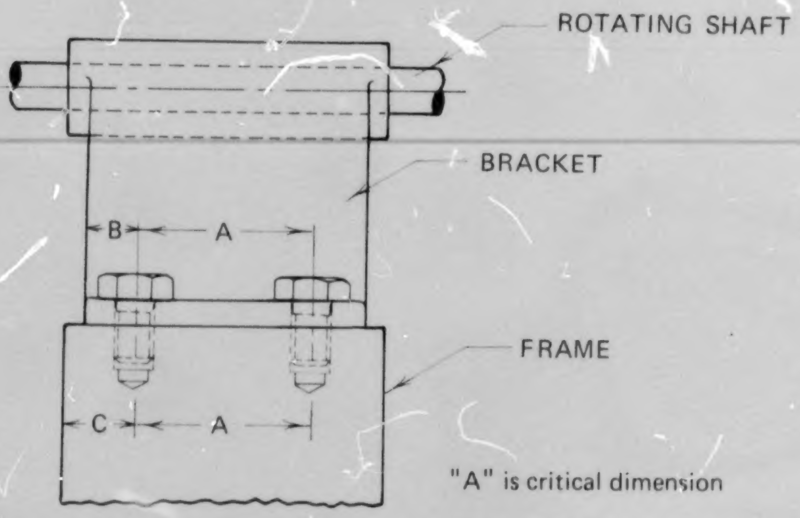
A. Dimensions common to both parts


MATING DIMENSION
MATING DIMENSION
MATING DIMENSION


M DRILL
M CBORE
M DEEP
M (thread note)
M DEEP
MATING
MATING
MATING
MATING
MATING
MATING

B. Single bracket assembly

(NOTE: Critical dimension "A" of frame must mate critical dimension "A" of bracket.)


ROTATING SHAFT
BRACKET
B
A
FRAME
C
A

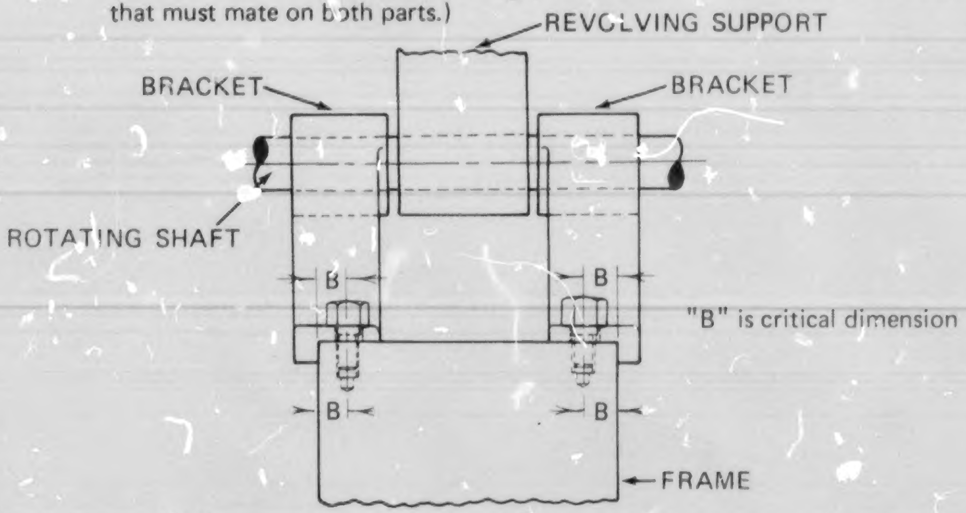
"A" is critical dimension

"B" and "C"
are not critical dimensions

INFORMATION SHEET

C. Double bracket assembly

(NOTE: With double bracket design, dimension "B" is critical dimension that must mate on both parts.)


REVOLVING SUPPORT
BRACKET
BRACKET
ROTATING SHAFT
B
B
"B" is critical dimension
B
B
FRAME

IV. Numerical control dimensioning

A. Datum or reference planes must be selected that are mutually perpendicular in the X, Y, and Z axes

B. Dimensions originate from the three planes

C. Dimensions must be in decimals

D. Angles should be in degrees and decimal parts of degrees

E. Standard tools such as reamers, drills, and tapers should be specified wherever possible

F. Tolerances should be used based on design requirements rather than tolerances of manufacturing machines

V. Fits

A. Fits for inch units

1. Running and sliding fits

a. RC 1 (Close sliding fits)

b. RC 2 (Sliding fits)

c. RC 3 (Precision running fits)

INFORMATION SHEET

- d. RC 4 (Close running fits)
- e. RC 5-RC 6 (Medium running fits)
- f. RC 7 (Free running fits)
- g. RC 8-RC 9 (Loose running fits)

2. Locational fits
   - a. LC 1-LC 11 (Locational clearance fits)
   - b. LT 1-LT 6 (Transition fits)
   - c. LN 1-LN 2 (Locational interference fits)

3. Force fits
   - a. FN 1 (Light drive fits)
   - b. FN 2 (Medium drive fits)
   - c. FN 3 (Heavy drive fits)
   - d. FN 4-FN 5 (Force fits)

B. Fits for metric units (SI)

1. Clearance fits

	HOLE BASIS	SHAFT BASIS
a.	H 11/c 11	C 11/h 11 (Loose running fits)
b.	H 9/d 9	D 9/h 9 (Free running fits)
c.	H 8/f 7	F 8/h 7 (Close running fits)
d.	H 7/g 6	G 7/h 6 (Sliding fits)
e.	H 7/h 6	H 7/h 6 (Locational clearance fits)

2. Transition fits

	HOLE	SHAFT
a.	H 7/k 6	K 7/h 6 (Locational transition fits)
b.	H 7/n 6	N 7/h 6 (Locational transition fits)

INFORMATION SHEET

3. Interference fits

	HOLE	**SHAFT**
a.	H 7/p 6	P 7/h 6 (Locational interference fits)
b.	H 7/s 6	S 7/h 6 (Medium drive fits)
c.	H 7/u 6	U 7/h 6 (Force fits)

VI. Calculation of limits in inch units using basic hole system (Transparency 4)

A. Calculation of limits for clearance fit

1. Refer to tolerance fit table for inch units, and locate basic hole size in **Nominal size range, inches** column

   (NOTE: Limits are in thousandths of an inch. Multiply limit by .001 for calculations.)

   Example: Basic hole size **2.00** fit **RC 6** --Go to table--

Nominal size range, inches	Limits of clearance	Standards limits	
		Hole	Shaft
1.97-3.15	2.5 7.3	+3.0 - 0	-2.5 -4.3

2. Calculate limits for the hole

   Example: 2.000 + 3.0 (.001) = 2.003 Max. limit (LMC)--largest hole
   2.000 − 0 = 2.000 Min. limit (MMC)--smallest hole

3. Calculate limits for the shaft

   Example: 2.000−2.5 (.001) = 1.9975 Max. limit (MMC)--largest shaft
   2.000−4.3 (.001) = 1.9957 Min. limit (LMC)--smallest shaft

4. Calculate allowance in inch units

   a. Calculate tightest fit (MMC of hole—MMC of shaft)
   smallest hole—largest shaft

   Example: 2.000−1.9975 = .0025

   b. Look at table under limits of clearance and check your answer against table

   Example: $\frac{.0025}{.001}$ = 2.5 which checks

INFORMATION SHEET

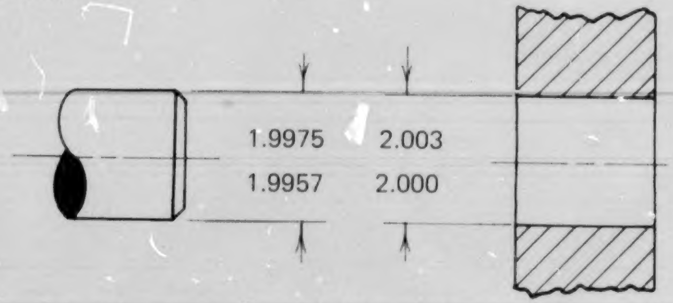
c. Calculate loosest fit (LMC of hole - LMC of shaft)
largest hole - smallest shaft

Example: 2.0030 – 1.9957 = .0073

d. Look at table under limits of clearance and check your answer against table

Example: $\frac{.0073}{.001}$ = 7.3 which checks

5. Dimension



B. Calculation of limits for locational fit

1. Refer to fit table for inch units, and locate basic hole size in **Nominal size range, inches** column

Example: Basic size **2.00** fit **LT 4** - go to table--

2. Calculate limits for the hole

Example: 2.00 + 1.8 (.001) = 2.0018 LMC
2.00 – 0 = 2.0000 MMC

3. Calculate limits for the shaft

Example: 2.00 + 1.3 (.001) = 2.0013 MMC
2.00 + .1 (.001) = 2.0001 LMC

4. Calculate fit

a. Calculate tightest fit (MMC of hole - MMC of shaft)

Example: 2.0000 – 2.0013 = - .0013

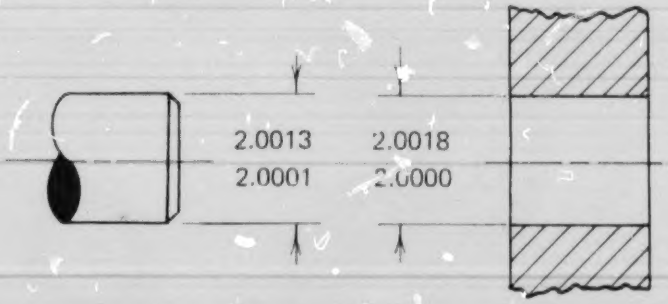
b. Calculate loosest fit (LMC of hole – LMC of shaft)

Example: 2.0018 – 2.0001 = + .0017

INFORMATION SHEET

c. Check table under fit to check your answer

5. Dimension



C. Calculation of limits for force fit

1. Refer to fit table for inch units, and locate basic hole size in **Nominal size range, inches** column

   Example: Basic size **2.00** fit **FN 3**; --Go to table--

2. Calculate limits for the hole

   Example: 2.00 + (1.2) (.001) = 2.0012 LMC
   2.00 − 0 = 2.0000 MMC

3. Calculate limits for the shaft

   Example: 2.00 + 3.2 (.001) = 2.0032 MMC
   2.00 + 2.5 (.001) = 2.0025 LMC

4. Calculate limits of interference

   a. Calculate tightest interference (MMC of hole − MMC of shaft)

      Example: 2.0000 − 2.0032 = −.0032

   b. Calculate loosest interference (LMC of hole − LMC of shaft)

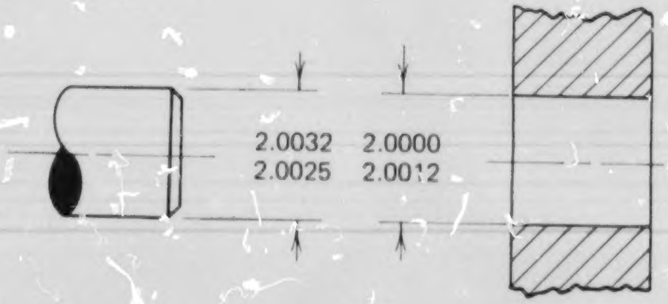
      Example: 2.0012 − 2.0025 = −.0013

      (NOTE: Notice both have negative values.)

   c. Check table under limits of interference to check your answer

INFORMATION SHEET

5. Dimension



VII. Calculation of limits in inch units using basic shaft system

A. Refer to fit table for inch units, and locate the basic shaft size

Example: Basic shaft size **2.00** fit **RC 6** --Go to table--

Nominal size range, inches	Limits of clearance	Standards limits	
		Hole	Shaft
1.97-3.15	2.5 7.3	+3.0 -0	-2.5 -4.3

B. Calculate basic hole size by adding allowance at MMC to basic shaft size

Example: 2.000 + .0025 = 2.0025 basic hole size

(NOTE: Now use table as we did in basic hole system.)

C. Calculate limits for the hole

Example: 2.0025 + 3.0 (.001) = 2.0055 LMC
2.0025−0 = 2.0025 MMC

D. Calculate limits for the shaft

Example: 2.0025−2.5 (.001) = 2.0000 MMC
2.0025−4.3 (.001) = 1.9982 LMC

E. Calculate allowance

1. Calculate tightest fit (MMC of hole - MMC of shaft)

   Example: 2.0025−2.0000 = .0025

2. Check allowance from table

INFORMATION SHEET

3. Calculate loosest fit (LMC of hole - LMC of shaft)

   Example: 2.0055 - 1.9982 = .0073

4. Check allowance from table

VIII. Calculation of limits in metric units using basic hole system (Transparency 5)

A. Calculation of limits for clearance fit

1. Refer to fit table for metric units, and locate basic size in Basic Size column

   Example: Basic hole size **40mm** fit **H7/g6** --Go to fit table--

Basic Size	Hole H7	Shaft g6	Fit
40 Max. Min.	40.025 40.000	39.991 39.975	0.050 0.009

2. Read from table hole limits

   Example: H7 40.025 maximum hole LMC
   H7 40.000 minimum hole MMC

3. Read from table shaft limits

   Example: g6 39.991 maximum shaft MMC
   g6 39.975 minimum shaft LMC

4. Calculate allowance

   a. Calculate tightest fit (MMC of hole - MMC of shaft)
   smallest hole - largest shaft

      Example: 40.000−39.991 = .009 mm

   b. Check table under minimum fit to check this calculation

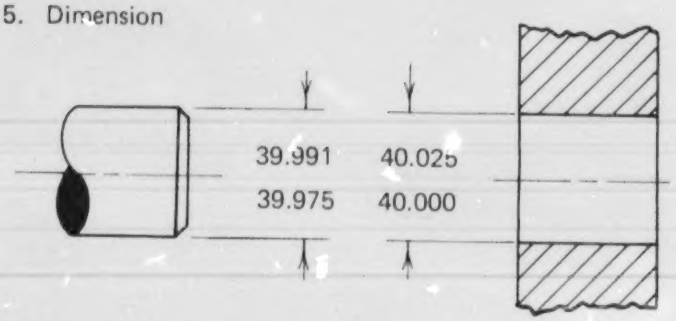
   c. Calculate loosest fit (LMC of hole - LMC of shaft)
   largest hole - smallest shaft

      Example: 40.025−39.975 = .050

   d. Check table under maximum fit to check this calculation

INFORMATION SHEET

5. Dimension



B. Calculation of limits for transition fit

1. Refer to fit table for metric units (SI), and locate basic size in **Basic Size** column

   Example: Basic size **40mm** fit **H7/k6** --Go to table--

2. Read from table hole limits

   Example: H7 40.025 LMC
   H7 40.000 MMC

3. Read from table shaft limits

   Example: k6 40.018 MMC
   k6 40.002 LMC

4. Calculate fit

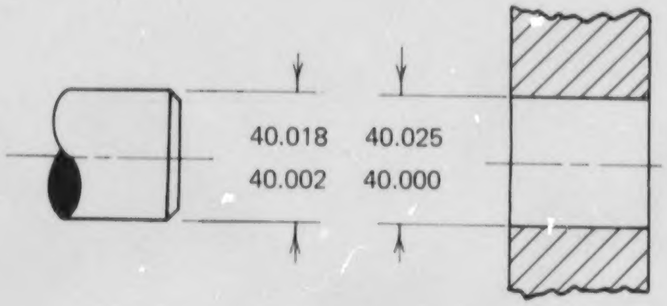
   a. Calculate tightest fit (MMC of hole−MMC of shaft)

      Example: 40.000−40.018 = −.018

   b. Calculate loosest fit (LMC of hole−LMC of shaft)

      Example: 40.025−40.002 = + .023

5. Dimension



INFORMATION SHEET

C. Calculation of limits for interference

1. Refer to fit table for metric units (SI), and locate basic size in **Basic Size** column

   Example: Basic size **50mm** fit **H7/u6** --Go to table--

2. Read from table hole limits

   Example: H7 50.025 LMC
   H7 50.000 MMC

3. Read from table shaft limits

   Example: u6 50.086 MMC
   u6 50.070 LMC

4. Calculate allowance

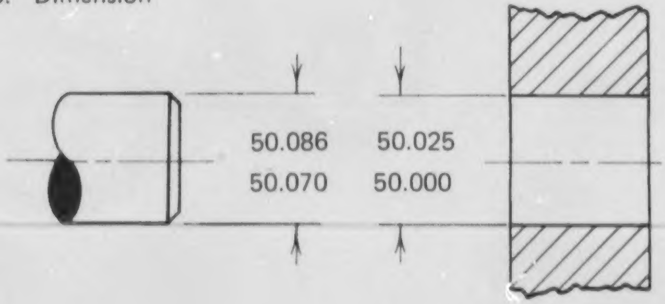
   a. Calculate tightest fit (MMC of hole–MMC of shaft)

      Example: 50.000–50.086 = –.086

   b. Calculate loosest fit (LMC of hole–LMC of shaft)

      Example: 50.025–50.070 = –.045

5. Dimension



IX. Tolerance ranges for shop processes

A. Processes (Transparency 6)

1. Lapping and honing - smallest tolerance - most expensive
2. Grinding, diamond turning, and boring
3. Broaching
4. Reaming

INFORMATION SHEET

    5. Turning, boring, slotting, planing, and shaping
    6. Milling
    7. Drilling - largest tolerance - least expensive
  B. Tolerance ranges
    1. Inch units
    2. Metric units--Multiply 25.4 times values in table

X. Hole size limits for standard dowels (Transparency 7)

  A. Clearance fit--limits of clearance given
    1. Tightest fit = MMC hole – MMC shaft
    2. Loosest fit = LMC hole – LMC shaft
    3. Limits of clearance: smallest number is tightest fit; largest number is loosest fit
  B. Interference fit--limits of interference given
    1. Tightest fit = MMC hole – MMC shaft
    2. Loosest fit = LMC hole – LMC shaft
    3. Limits of interference: largest number is tightest fit and is negative; smallest number is loosest fit and is negative

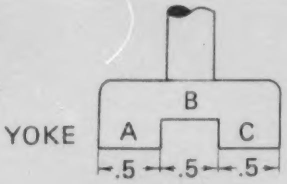
XI. Limit dimensions for interchangeability of parts

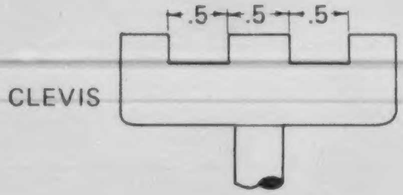
  A. Parts should be toleranced to fit end-for-end to make assembly easier if function is not affected (Transparencies 8 and 9)

INFORMATION SHEET

B. Find limit dimensions of each part and dimension so parts fit end-for-end

Example: Nominal size .500; .004 maximum
accumulation of tolerance; clearance
between each mating part .005;
loosest fit not to exceed .015





C. Since parts must fit end-for-end, the limit dimensions must be the same on both ends

D. Select the center dimension to be basic size

(NOTE: It could be yoke or clevis. Yoke was selected for the following example.)

Example: Yoke (B) MMC .500
clearance −.005
Clevis (B) MMC .495

E. Distribute maximum accumulation equally on each side of parts

(NOTE: As you can see in the following example, 3 does not divide into .004 evenly, so we give .002 to the center (B) and .001 to both sides A and C.)

Example: .002 tolerance distribution
.001 tolerance distribution
.001 tolerance distribution
.004 maximum accumulation

F. Calculate LMC for center (B)

Example: Yoke (B) MMC= .500
(B) Tol. = + .002
Yoke (B) LMC = .502

Clevis (B) MMC= .495
(B) Tol. = −.002
Clevis (B) LMC = .493

(NOTE: The + and − signs are for LMC; that is, if a feature is like a hole, LMC is "+,"; if a feature is like a shaft, it is "−.")

INFORMATION SHEET

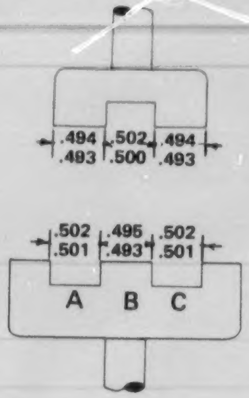
G. Calculate MMC for sides (A or C)

1. Use LMC of yoke (B) for LMC of clevis (A) or (C)

Example: Clevis (A) or (C) LMC = .502
Tol. dist. = −.001
Clevis (A) or (C) MMC = .501

2. Use LMC of clevis (B) for LMC of yoke (A) or (C)

Example: Yoke (A) or (C) LMC = .493
Tol. dist. = +.001
Yoke (A) or (C) MMC = .494



H. When each part is toleranced, an accumulation of tolerance must be checked

1. Add up maximum and minimum values

Example:

Max. of yoke	Min. of yoke
.494	.493
.502	.500
.494	.493
1.490	1.486

Max. of clevis	Min. of clevis
.502	.501
.495	.493
.502	.501
1.499	1.495

2. Subtract minimum of each part from the maximum of mating part

Example: Max. of yoke − Min. of clevis = clearance (overall)
Max. of clevis − Min. of yoke = loosest fit

1.490 − 1.495 = .005 (checks for clearance)
1.499 − 1.486 = .013 (checks within loosest fit)

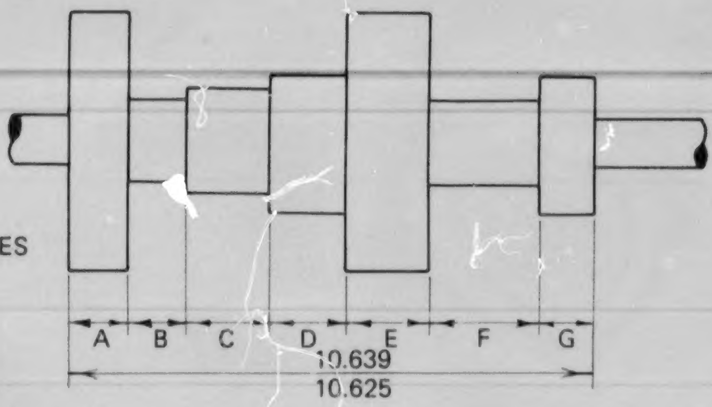
INFORMATION SHEET

XII. Steps for determining limit dimensions for intermediate parts to retain overall limits (Transparency 10)

(NOTE: Always use largest possible tolerance.)

A. Find limit dimensions

Example:



BASIC SIZES

A	1.375
B	1.250
C	1.750
D	1.500
E	1.750
F	2.000
G	1.000

B. Subtract upper and lower limits of overall dimension to get total tolerance accumulation

Example: 10.639 – 10.625 = .014 total tolerance accumulation

C. Divide total tolerance accumulation by number of toleranced parts to get tolerance per part

Example: $\frac{.014}{7}$ = .002 tolerance per part

D. Add tolerance per part to each basic size to get upper limit of each part

Example:

$$\begin{array}{r}1.375\\ +.002\\ \hline 1.377\end{array}\quad\begin{array}{r}1.250\\ +.002\\ \hline 1.252\end{array}\quad\begin{array}{r}1.750\\ +.002\\ \hline 1.752\end{array}\quad\begin{array}{r}1.500\\ +.002\\ \hline 1.502\end{array}$$

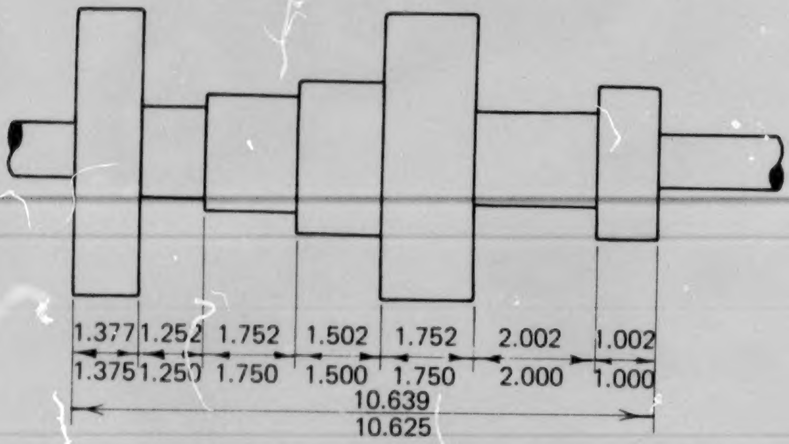
$$\begin{array}{r}1.750\\ +.002\\ \hline 1.752\end{array}\quad\begin{array}{r}2.000\\ +.002\\ \hline 2.002\end{array}\quad\begin{array}{r}1.000\\ +.002\\ \hline 1.002\end{array}$$

(NOTE: The lower limit is basic size.)

INFORMATION SHEET

E. Check by adding upper limits together to get upper limit of overall dimension

Example: 1.377 + 1.252 + 1.752 + 1.502 + 1.752 + 2.002 + 1.002=10.639


1.377
1.375
1.252
1.250
1.752
1.750
1.502
1.500
1.752
1.750
2.002
2.000
1.002
1.000
10.639
10.625

XIII. Characteristic symbols for tolerances of position and form (Transparency 11)

		Characteristic Symbols	
Form Tolerances	Individual Features	Straightness	—
		Flatness	▱
		Roundness; Circularity	○
		Cylindricity	⌭
	Individual or Related Features	Profile of a line	⌒
		Profile of a surface	⌓
	Related Features	Angularity	∠
		Perpendicularity	⊥
		Parallelism	//
Location Tolerances		Position	⌖
		Concentricity	◎
		Symmetry	⌯
Runout Tols.		Circular	↗
		Total	↗

INFORMATION SHEET

XIV. Terms and supplementary symbols for tolerances of position and form (Transparency 11)

- A. Maximum material condition (MMC)-- Ⓜ
- B. Regardless of feature size (RFS)-- Ⓢ
- C. Diameter (DIA)-- ⌀
- D. Reference (Ref)-- (   )
- E. Basic (BSC)-- ▭
- F. Projected tolerance zone-- Ⓟ

XV. Position and form symbols (Transparencies 12 and 13)

- A. Basic dimension symbol
- B. Datum symbol with datum reference
- C. Feature control symbols
  - 1. Geometric characteristic symbol
  - 2. Tolerance
  - 3. Modifier
- D. Feature control symbols with datum references
  - 1. Symbol
  - 2. Datum reference to one or two datums
  - 3. Tolerance
  - 4. Modifier
    - a. Of datum
    - b. Of tolerance

XVI. Descriptions of position and form

- A. No specified tolerance of form (Transparency 14)
- B. Straightness (Transparency 15)
- C. Flatness (Transparency 16)

INFORMATION SHEET

- D. Roundness (Transparency 17)
- E. Cylindricity (Transparency 18)
- F. Profile of a surface (Transparency 19)
- G. Profile of a surface between points (Transparency 20)
- H. Angularity (Transparency 21)
- I. Perpendicularity (Transparencies 22 and 23)
- J. Parallelism (Transparency 24)
- K. Concentricity (Transparency 25)
- L. Symmetry (Transparency 26)

XVII. Positional tolerancing (Transparency 27)

- A. Tolerance zones (Transparency 28)
  1. Conventional limit location dimensions have a square tolerance zone
  2. Positional tolerancing allows a circular tolerance zone
- B. Cylindrical tolerance zones (Transparency 29)--Positional tolerancing allows more tolerance than conventional limit dimensions
- C. No tolerance accumulation is found in positional tolerancing (Transparency 30)
- D. Extreme angular variation in drilling a hole under positional tolerancing is possible

XVIII. Maximum material condition (MMC) and regardless of feature size (RFS)

- A. MMC--Less restrictive (Transparency 31)
- B. RFS--More restrictive (Transparency 32)

XIX. Angular tolerances (Transparency 33)

- A. Bilateral angular tolerances--Cause a larger tolerance zone as you move from the vertex
- B. Basic angular tolerances--Using angular feature controls causes a parallel tolerance zone

XX. Purpose of surface quality specifications--Used where heavy loads and high speeds with less friction are needed

Example: Aerospace, automotive, and aircraft industries

INFORMATION SHEET

XXI. Parts of a surface quality symbol (Transparency 34)

- A. Roughness height
- B. Waviness height
- C. Waviness width
- D. Roughness width cutoff
- E. Lay
- F. Roughness width

XXII. Surface quality notes

- A. Values are in micrometers or microinches
- B. Higher number of micrometers or inches indicates rougher surface
- C. Symbol is always made in the standard upright position
- D. The roughest surface that will satisfy function and form is the ideal finish

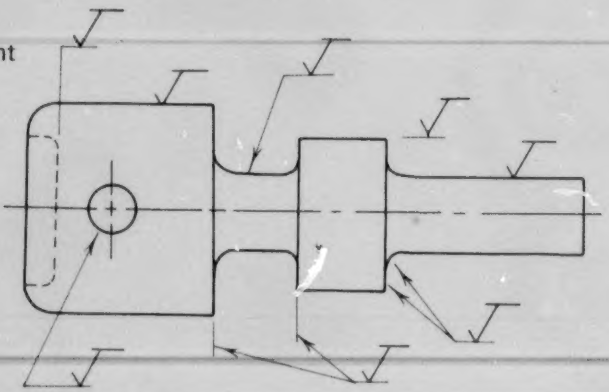
XXIII. Lay symbols (Transparency 35)

- A. =--Parallel to surface
- B. ⊥--Perpendicular to surface
- C. X--Angular to surface
- D. M--Multidirectional
- E. C--Circular
- F. R--Radial
- G. P^3--Particulate, non-directional, or protuberant

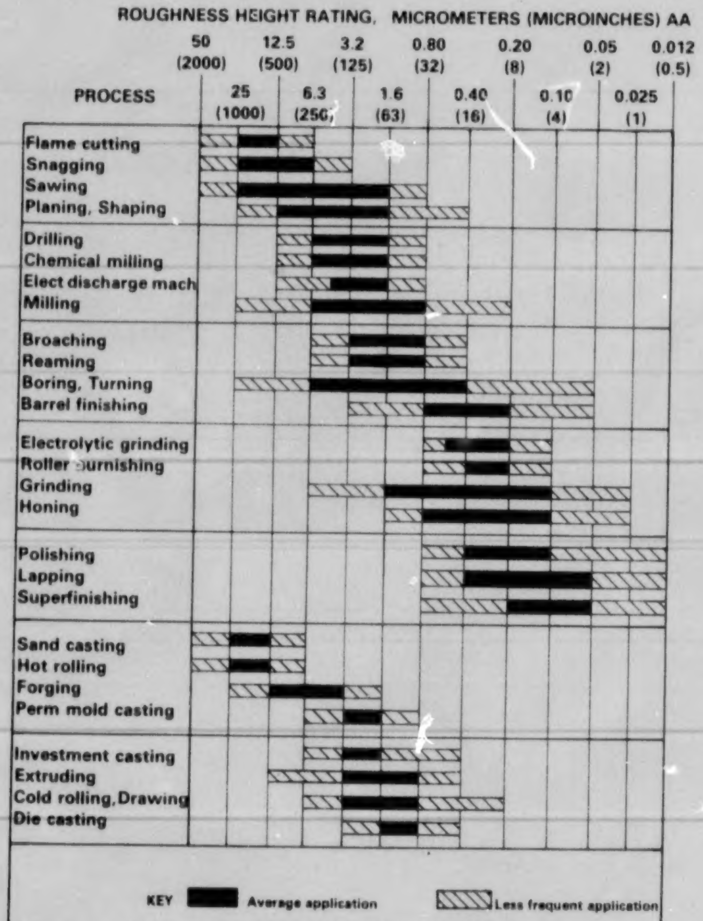
XXIV. Placement of surface quality symbols

- A. Placed on edge of surface
- B. Read from bottom of sheet

C. Typical placement



XXV. Surface roughness produced by common production methods



The ranges shown above are typical of the processes listed.
Higher or lower values may be obtained under special conditions.

INFORMATION SHEET

XXVI. Recommended values for surface quality symbols

A. Roughness average rating values--Preferred values in boldface type

Recommended Roughness
Average Rating Values
Micrometers (Microinches)

μm	μin.	μm	μin.
0.025	(1)	1.25	(50)
0.050	**(2)**	**1.6**	**(63)**
0.075	(3)	2.0	(80)
0.100	**(4)**	2.5	(100)
0.125	(5)	**3.2**	**(125)**
0.15	(6)	4.0	(160)
0.20	**(8)**	5.0	(200)
0.25	(10)	**6.3**	**(250)**
0.32	(13)	8.0	(320)
0.40	**(16)**	10.0	(400)
0.50	(20)	**12.5**	**(500)**
0.63	(25)	15.0	(600)
0.80	**(32)**	20.0	(800)
1.00	(40)	25.0	(1000)

B. Waviness height values--Preferred values in boldface type

Recommended Waviness
Height Values,
Millimeters (Inches)

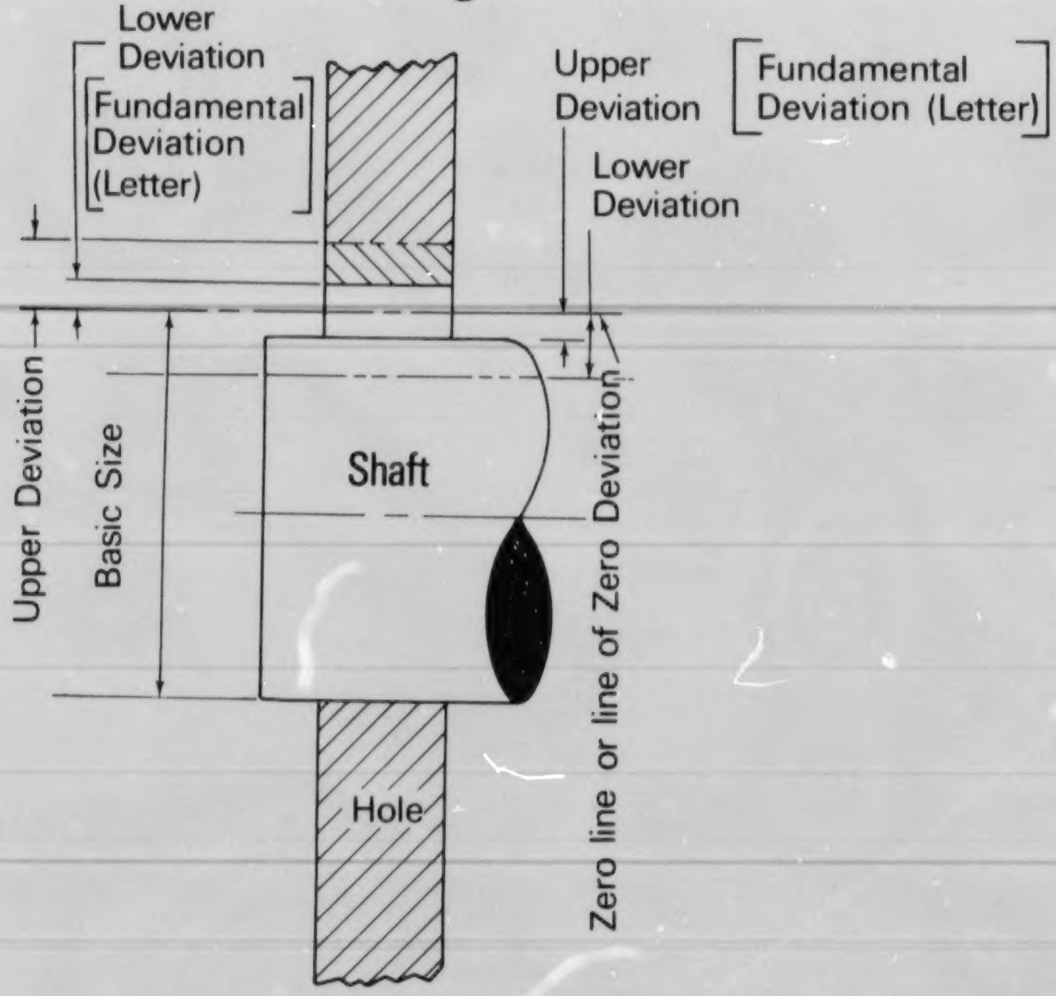
mm	in.	mm	in.
0.0005	**(.00002)**	**0.025**	**(.0010)**
0.008	(.00003)	**0.05**	**(.002)**
0.0012	**(.00005)**	0.08	(.003)
0.0020	(.0008)	**0.12**	**(.005)**
0.0025	**(.00010)**	0.20	(.008)
0.005	**(.0002)**	**0.25**	**(.010)**
0.008	(.0003)	0.38	(.015)
0.012	**(.0005)**	**0.50**	**(.020)**
0.020	(.0008)	0.80	(.030)

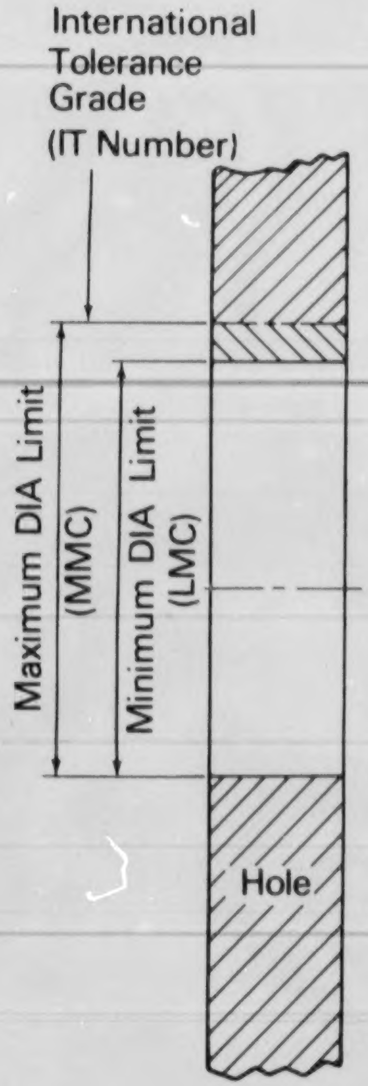
C. Roughness width cutoff values--Preferred values in boldface type

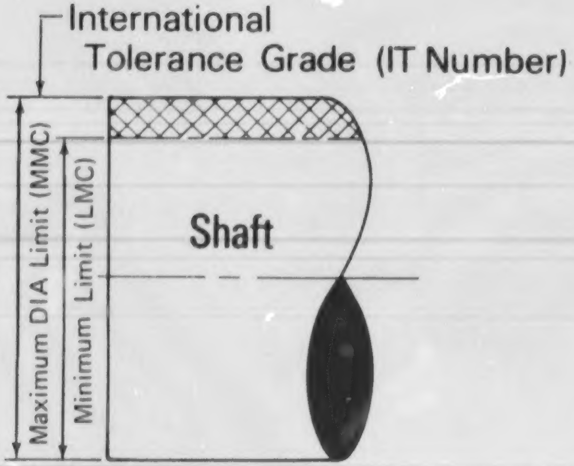
Recommended
Standard Roughness
Width Cutoff Values
Millimeters (Inches)

mm	in.	mm	in.
0.08	(0.03)	2.50	(.100)
0.25	(.013)	8.0	(.300)
0.80	**(.030)**	25.0	(1.000)

Tolerancing Terms


Lower Deviation
Fundamental Deviation (Letter)
Upper Deviation
Fundamental Deviation (Letter)
Lower Deviation
Upper Deviation
Basic Size
Shaft
Zero line or line of Zero Deviation
Hole


International Tolerance Grade (IT Number)
Maximum DIA Limit (MMC)
Minimum DIA Limit (LMC)
Hole

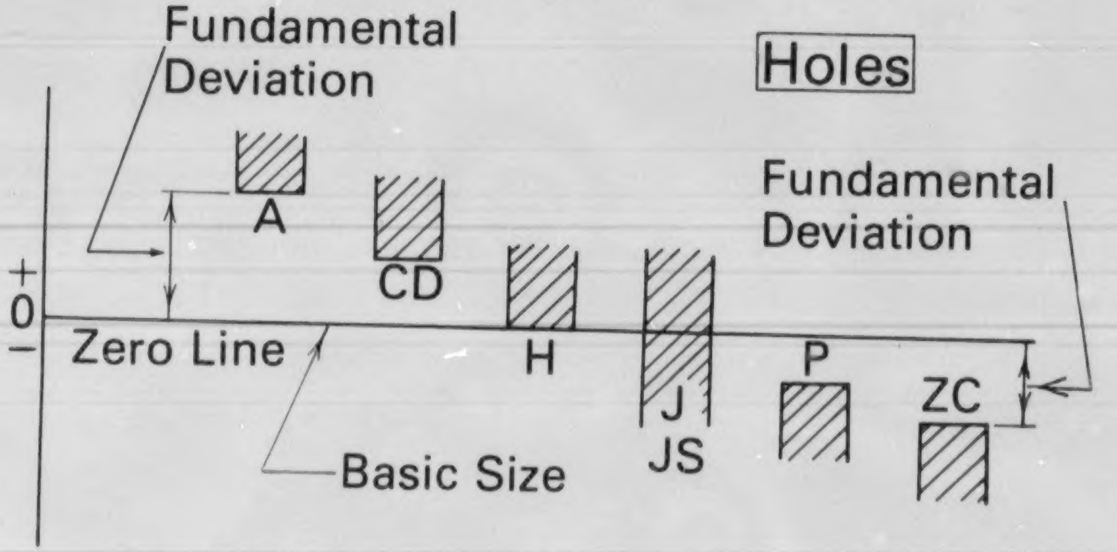

International Tolerance Grade (IT Number)
Shaft
Maximum DIA Limit (MMC)
Minimum Limit (LMC)

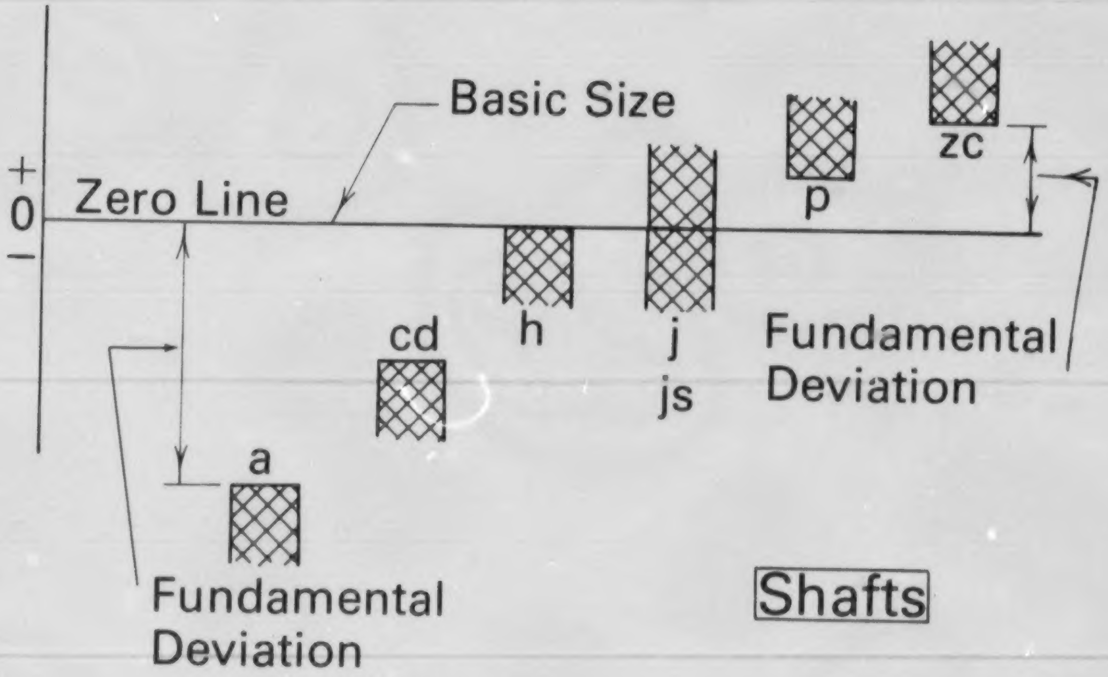
Overlay 1B

MD - 255

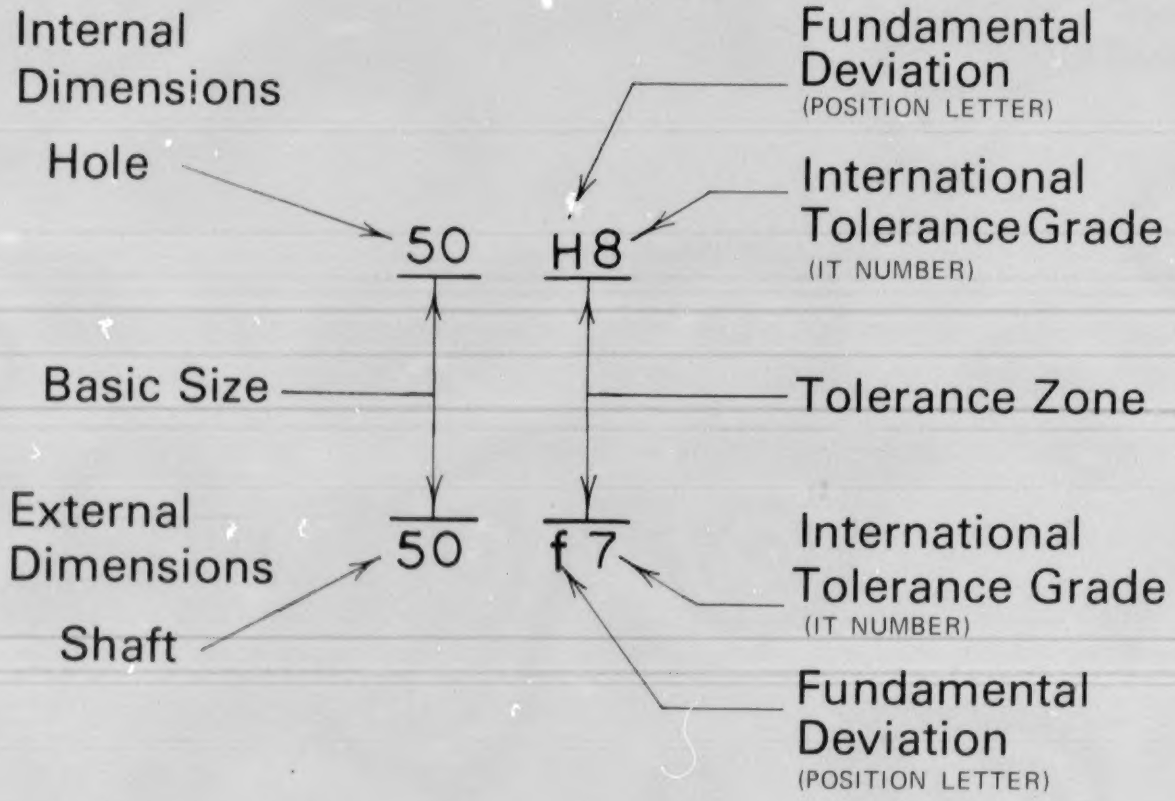
Graphical Representation of Tolerance Zones

(Metric)


Fundamental Deviation
Holes
A
CD
H
J
JS
P
ZC
Fundamental Deviation
+
0
−
Zero Line
Basic Size


Basic Size
zc
p
+
0
−
Zero Line
h
j
js
cd
a
Fundamental Deviation
Fundamental Deviation
Shafts

Metric Tolerance Designation



Internal Dimensions

Hole

50 H8

Fundamental Deviation (POSITION LETTER)

International Tolerance Grade (IT NUMBER)

Basic Size

Tolerance Zone

External Dimensions

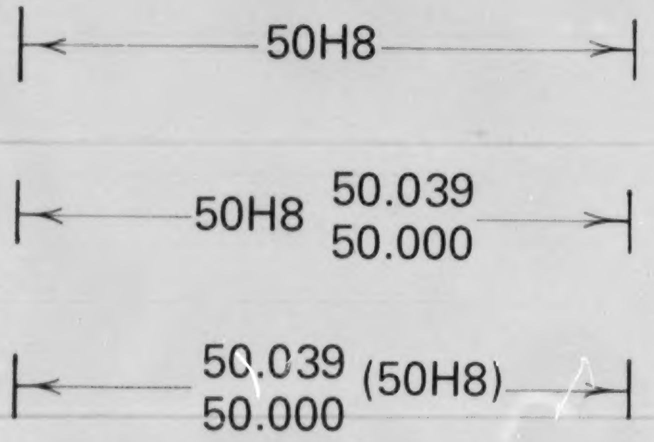
Shaft

50 f 7

International Tolerance Grade (IT NUMBER)

Fundamental Deviation (POSITION LETTER)

Designations of Tolerances on Drawings



(a) 50H8

(b) 50H8 50.039 / 50.000

(c) 50.039 / 50.000 (50H8)

Determining Limits for Hole and Shaft (Inch Units)

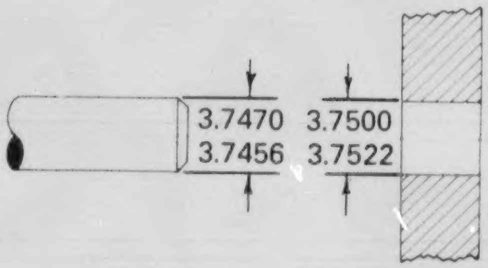
Tolerance Fit Table

Nominal Size Range inches	Class RC 5			Class RC 6			Class LT 3			Class LT 4		
Over To	Limits of Clearance	Standard Limits Hole H8	Standard Limits Shaft e7	Limits of Clearance	Standard Limits Hole H9	Standard Limits Shaft e8	Fit	Standard Limits Hole H7	Standard Limits Shaft k6	Fit	Standard Limits Hole H8	Standard Limits Shaft k7
0 - 0.12	0.6 1.6	+0.6 -0	-0.6 -1.0	0.6 2.2	+1.0 -0	-0.6 -1.2						
0.12- 0.24	0.8 2.0	+0.7 -0	-0.8 -1.3	0.8 2.7	+1.2 -0	-0.8 -1.5						
0.24- 0.40	1.0 2.5	+0.9 -0	-1.0 -1.6	1.0 3.3	+1.4 -0	-1.0 -1.9	-0.5 +0.5	+0.6 -0	+0.5 +0.1	-0.7 +0.8	+0.9 -0	+0.7 +0.1
0.40- 0.71	1.2 2.9	+1.0 -0	-1.2 -1.9	1.2 3.8	+1.6 -0	-1.2 -2.2	-0.5 +0.6	+0.7 -0	+0.5 +0.1	-0.8 +0.9	+1.0 -0	+0.8 +0.1
0.71- 1.19	1.6 3.6	+1.2 -0	-1.6 -2.4	1.6 4.8	+2.0 -0	-1.6 -2.8	-0.6 +0.7	+0.8 -0	+0.6 +0.1	-0.9 +1.1	+1.2 -0	+0.9 +0.1
1.19- 1.97	2.0 4.6	+1.6 -0	-2.0 -3.0	2.0 6.1	+2.5 -0	-2.0 -3.6	-0.7 +0.9	+1.0 -0	+0.7 +0.1	-1.1 +1.5	+1.6 -0	+1.1 +0.1
1.97- 3.15	2.5 5.5	+1.8 -0	-2.5 -3.7	2.5 7.3	+3.0 0	-2.5 -4.3	-0.8 +1.1	+1.2 0	+0.8 +0.1	-1.3 +1.7	+1.8 -0	+1.3 +0.1
3.15- 4.73	3.0 6.6	+2.2 -0	-3.0 -4.4	3.0 8.7	+3.5 -0	3.0 5.2	-1.0 +1.3	+1.4 0	+1.0 +0.1	-1.5 +2.1	+2.2 -0	+1.5 +0.1

Basic hole system. Limits are in thousandths of an inch

Nominal Size Range inches	Class FN 3			Class FN 4		
Over To	Limits of Interference	Standard Limits Hole H7	Standard Limits Shaft t6	Limits of Interference	Standard Limits Hole H7	Standard Limits Shaft u6
0 - 0.12				0.3 0.95	+0.4 -0	+ 0.95 + 0.7
0.12- 0.24				0.4 1.2	+0.5 -0	+ 1.2 + 0.9
0.24- 0.40				0.6 1.6	+0.6 -0	+ 1.6 + 1.2
0.40- 0.56				0.7 1.8	+0.7 -0	+ 1.8 + 1.4
0.56- 0.71				0.7 1.8	+0.7 -0	+ 1.8 + 1.4
0.71- 0.95				0.8 2.1	+0.8 -0	+ 2.1 + 1.6
0.95- 1.19	0.8 2.1	+0.8 -0	+ 2.1 + 1.6	1.0 2.3	+0.8 -0	+ 2.3 + 1.8
1.19- 1.58	1.0 2.6	+1.0 -0	+ 2.6 + 2.0	1.5 3.1	+1.0 -0	+ 3.1 + 2.5
1.58- 1.97	1.2 2.8	+1.0 -0	+ 2.8 + 2.2	1.8 3.4	+1.0 -0	+ 3.4 + 2.8
1.97- 2.56	1.3 3.2	+1.2 -0	+ 3.2 + 2.5	2.3 4.2	+1.2 -0	+ 4.2 + 3.5

Problem: Find limits for shaft and hole
Basic Size = 3.75
RC 5 Fit



Solution:

1. From tol fit table
   Hole + 2.2 Shaft -3.0
   - 0 -4.4
2. Hole

3.7500	3.7500
+ .0022	- . 0
3.7522	3.7500

3. Shaft

3.7500	3.7500
- .0030	- .0044
3.7470	3.7456

4. Check Clearance
   Tightest fit MMC
   3.7500 Hole
   -3.7470 Shaft
   .0030
   Loosest fit LMC
   3.7522 Hole
   -3.7456 Shaft
   .0066
5. Check table under limits of fit

Determining Limits for Hole and Shaft (Metric Units)

Tolerance
Fit
Table

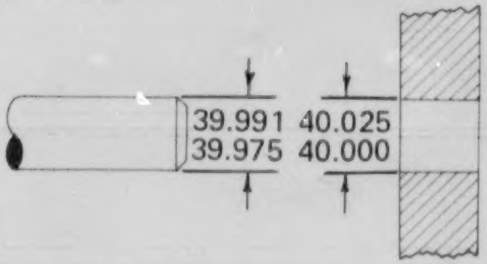
Clearance Fits, Hole Basis

BASIC SIZE		LOOSE RUNNING Hole H11	Shaft c11	Fit	FREE RUNNING Hole H9	Shaft d9	Fit	CLOSE RUNNING Hole H8	Shaft f7	Fit	SLIDING Hole H7	Shaft g6	Fit	LOCATIONAL CLEARANCE Hole H7	Shaft h6	Fit
40	MAX	40.160	39.880	0.440	40.062	39.920	0.204	40.039	39.975	0.089	40.025	39.991	0.050	40.025	40.000	0.041
	MIN	40.000	39.720	0.120	40.000	39.858	0.080	40.000	39.950	0.025	40.000	39.975	0.009	40.000	39.984	0.000
50	MAX	50.160	49.870	0.450	50.062	49.920	0.204	50.039	49.975	0.089	50.025	49.991	0.050	50.025	50.000	0.041
	MIN	50.000	49.710	0.130	50.000	49.858	0.080	50.000	49.950	0.025	50.000	49.975	0.009	50.000	49.984	0.000
60	MAX	60.190	59.860	0.520	60.074	59.900	0.248	60.046	59.970	0.106	60.030	59.990	0.059	60.030	60.000	0.049
	MIN	60.000	59.670	0.140	60.000	59.826	0.100	60.000	59.940	0.030	60.000	59.971	0.010	60.000	59.981	0.000
80	MAX	80.190	79.850	0.530	80.074	79.900	0.248	80.046	79.970	0.106	80.030	79.990	0.059	80.030	80.000	0.049
	MIN	80.000	79.660	0.150	80.000	79.826	0.100	80.000	79.940	0.030	80.000	79.971	0.010	80.000	79.981	0.000
100	MAX	100.220	99.830	0.610	100.087	99.880	0.294	100.054	99.964	0.125	100.035	99.988	0.069	100.035	100.000	0.057
	MIN	100.000	99.610	0.170	100.000	99.793	0.120	100.000	99.929	0.036	100.000	99.966	0.012	100.000	99.978	0.000
120	MAX	120.220	119.820	0.620	120.087	119.880	0.294	120.054	119.964	0.125	120.035	119.988	0.069	120.035	120.000	0.057
	MIN	120.000	119.600	0.180	120.000	119.793	0.120	120.000	119.929	0.036	120.000	119.966	0.012	120.000	119.978	0.000
160	MAX	160.250	159.790	0.710	160.100	159.855	0.345	160.063	159.957	0.146	160.040	159.986	0.079	160.040	160.000	0.065
	MIN	160.000	159.540	0.210	160.000	159.755	0.145	160.000	159.917	0.043	160.000	159.961	0.014	160.000	159.975	0.000

(NOTE: Dimensions are in mm.)

ANSI B4.2 1978

Problem:
Find limits for shaft and hole
Basic Size = 40mm
Fit H7/g6



Solution:

1. From tol fit tables, locate 40mm basic size

2. Hole limits
   H7 40.025 LMC (Max hole)
   40.000 MMC (Min hole)

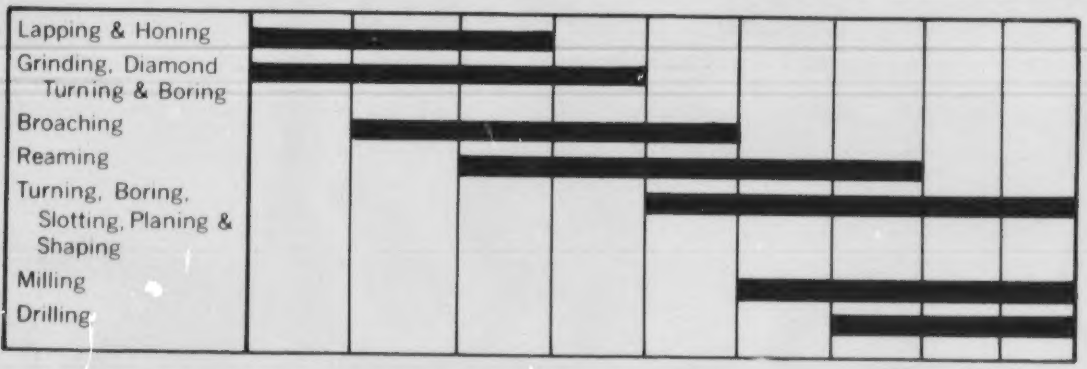
3. Shaft limits
   g6 39.991 MMC (Max shaft)
   39.975 LMC (Min shaft)

4. Check Clearance
   Tightest fit MMC
   40.000 Hole
   -39.991 Shaft
   .009
   Loosest fit LMC
   40.025 Hole
   -39.975 Shaft
   .050

5. Check table under limits of fit

Tolerances Related to Shop Processes

Range of Sizes		Tolerances								
From	To & Incl.									
.000	.599	.00015	.0002	.0003	.0005	.0008	.0012	.002	.003	.005
.600	.999	.00015	.00025	.0004	.0006	.001	.0015	.0025	.004	.006
1.000	1.499	.0002	.0003	.0005	.0008	.0012	.002	.003	.005	.008
1.500	2.799	.00025	.0004	.0006	.001	.0015	.0025	.004	.006	.010
2.800	4.499	.0003	.0005	.0008	.0012	.002	.003	.005	.008	.012
4.500	7.799	.0004	.0006	.001	.0015	.0025	.004	.006	.010	.015
7.800	13.599	.0005	.0008	.0012	.002	.003	.005	.008	.012	.020
13.600	20.999	.0006	.001	.0015	.0025	.004	.006	.010	.015	.025

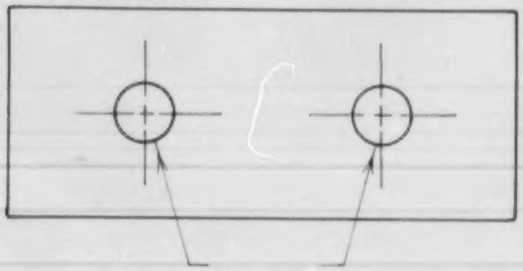


Hole Size for Standard Dowel

(Fit Dimensions)

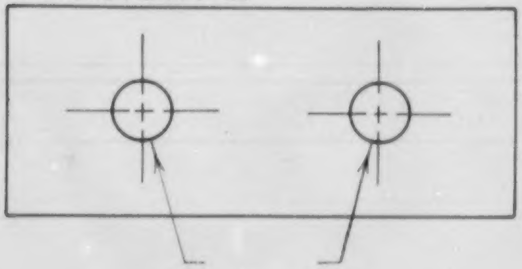
Directions: Determine Hole Limits for Each Mating Situation with Defined Dowel & Fit Limits.

Problem 1



Dowel .2502 MMC
.2500 LMC
RC3 Fit
Limits of
Clearance
.0005, –.0015

Problem 2



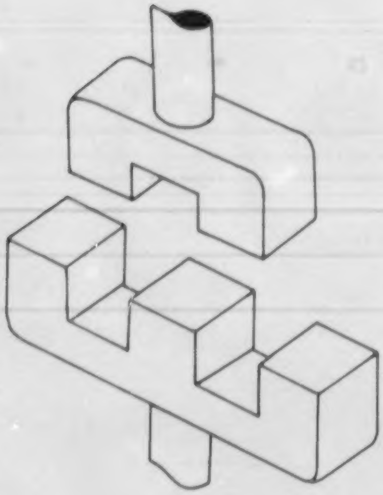
Dowel .2502 MMC
.2500 LMC
FN2 - Fit
Limits of
Interference
.0004, –.0014

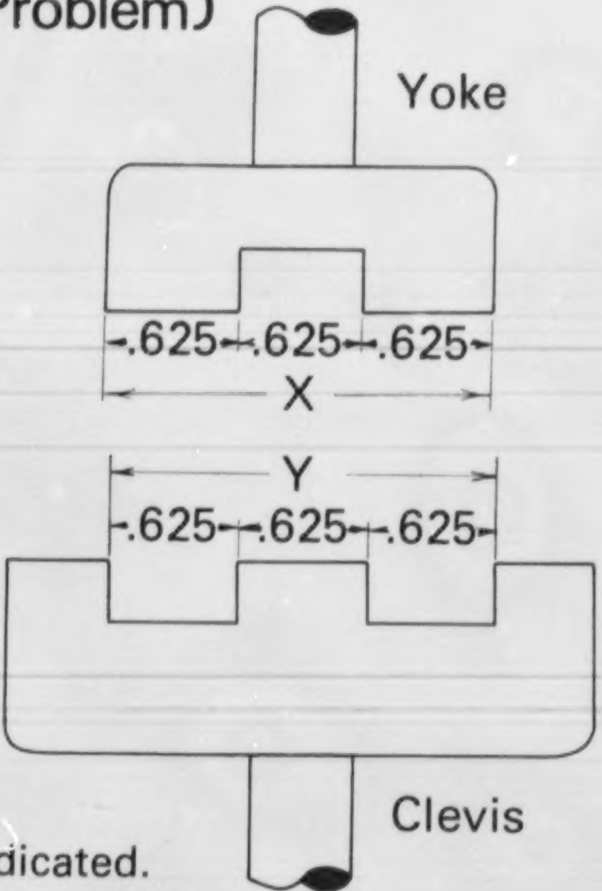
.2515
.2507
Tightest Fit = MMC of Hole – MMC of Shaft
.0005 = MMC of Hole – .2502
.2507 = MMC of Hole
Loosest Fit = LMC of Hole – LMC of Shaft
.0015 = LMC of Hole – .2500
.2515 = LMC of Hole

.2496
.2488
Tightest Fit = MMC of Hole – MMC of Shaft
–.0014 = MMC of Hole – .2502
.2488 = MMC of Hole
Loosest Fit = LMC of Hole – LMC of Shaft
–.0004 = LMC of Hole – .2500
.2496 = LMC of Hole

Interchangeability of Mating Parts

(Problem)



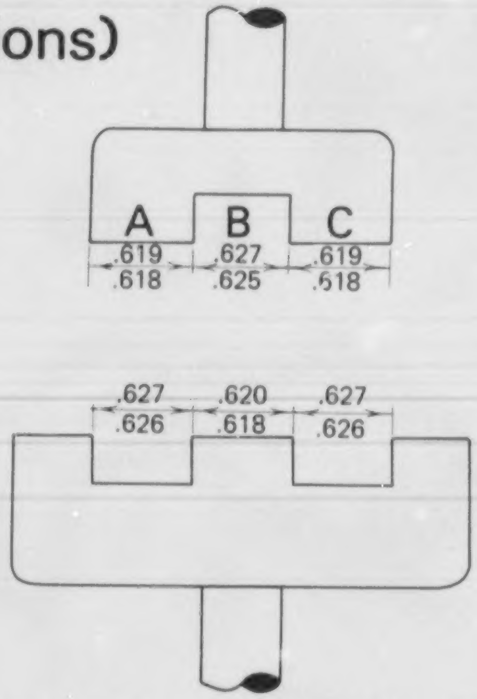


Data:

A. Basic sizes are as indicated.
B. Maximum accumulation of tolerance is .004 which may be X or Y.
C. Required clearance allowance between each set of mating components is .005.
D. Loosest fit not to exceed .015.
E. Dimension each component on the yoke and also on the clevis, in limit form so that the fit requirements are maintained.
F. Dimension so that yoke can be turned end-for-end and the parts will assemble with required clearance values.

Interchangeability of Mating Parts

(Calculations)



1. Yoke (B) MMC .625
Clearance $-.005$
Clevis (B) MMC .620

2. (B) .002 Tol dist.
(A) .001 Tol dist.
(C) .001 Tol dist.
.004 Max Accum

3. Yoke (B) MMC = .625
(B) Tol = +.002
Yoke (B) LMC = .627

4. Clevis (B) MMC = .620
(B) Tol = $-.002$
Clevis (B) LMC = .618

5. Clevis (A) or (B) LMC
= .627
(From Yoke [B] LMC)

6. Clevis (A) or (B) LMC = .627
Tol dist. = $-.001$
Clevis (A) or (B) MMC = .626

7. Yoke (A) or (B) LMC
= .618

8. Yoke (A) or (B) LMC = .618
Tol dist. = +.001
Yoke (A) or (B) MMC = .619

9. Check Maximum and Minimum

Max of Yoke	Min of Yoke	Max of Clevis	Min of Clevis
.619	.618	.627	.626
.627	.625	.620	.618
.619	.618	.627	.626
1.865	1.861	1.874	1.870

1.870 – 1.865 = .005 (Within Overall Clearance)
1.874 – 1.861 = .013 (Within Loosest Fit)

Limits for Intermediate Parts

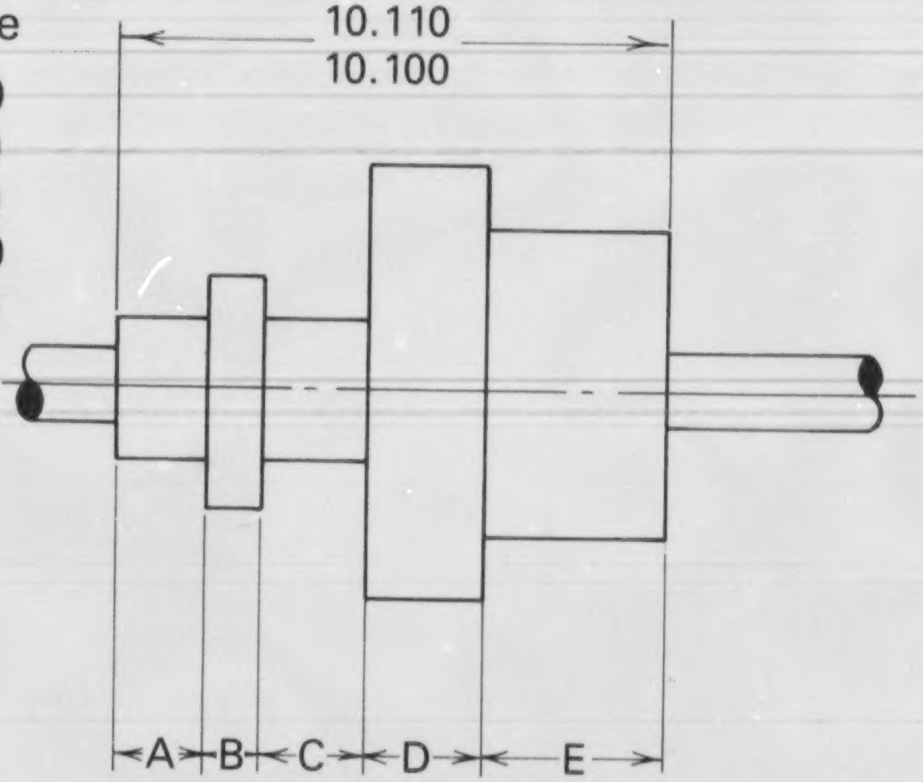
A. Dimension the Intermediate Parts to Retain Overall Limits.

B. Use Largest Possible Tolerance.

C. Give Dimensions in Limit Form.

Basic Size

A	1.500
B	1.350
C	1.500
D	2.000
E	3.750



Limits

A. ____________ B. ____________ C. ____________

D. ____________ E. ____________

ANSWERS

1.502	1.352	1.502
1.500	1.350	1.500
2.002	3.752	
2.000	3.750	

Symbols for Tolerances of Position and Form

		Characteristic Symbols	
Form Tolerances	Individual Features	Straightness	—
		Flatness	▱
		Roundness; Circularity	○
		Cylindricity	⌭
	Individual or Related Features	Profile of a line	⌒
		Profile of a surface	⌓
	Related Features	Angularity	∠
		Perpendicularity	⊥
		Parallelism	//
Location Tolerances		Position	⌖
		Concentricity	◎
		Symmetry	⌯
Runout Tols.		Circular	↗
		Total	↗

Supplementary Symbols		
MMC	Maximum material condition	Ⓜ
RFS	Regardless of feature size	Ⓢ
DIA	Diameter	∅
REF	Reference	(1.250)
BSC	Basic	$\boxed{3.875}$
	Projected Tolerance Zone	Ⓟ

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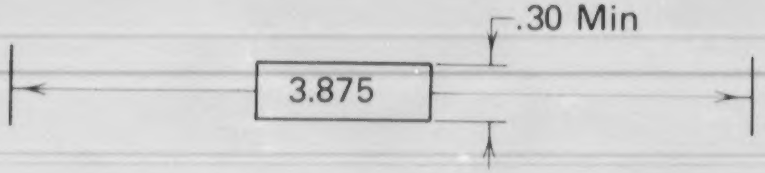
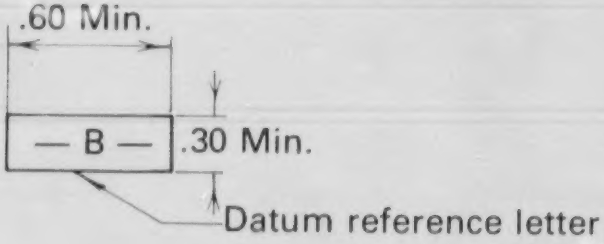
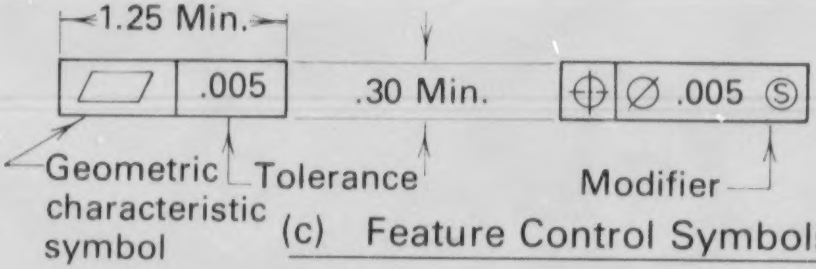
Use of Symbols for Tolerances of Position and Form



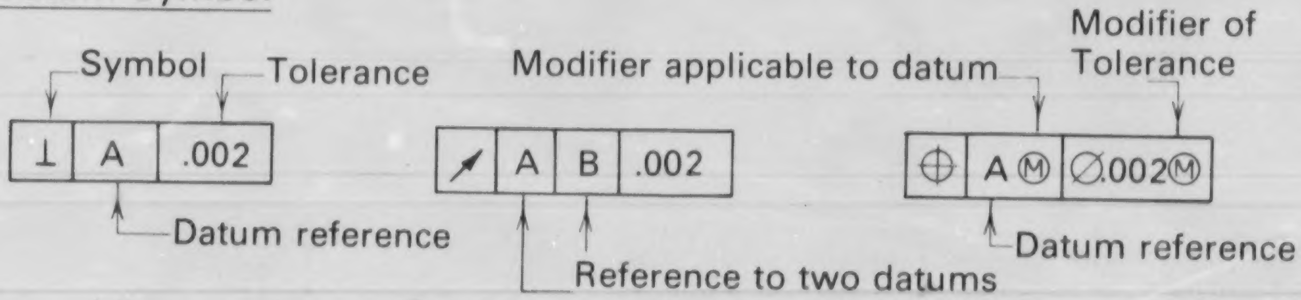
(a) Basic Dimension Symbol


.60 Min.
— B —
.30 Min.
Datum reference letter

(b) Datum Symbol


1.25 Min.
.005
.30 Min.
⌖ ⌀ .005 Ⓢ
Geometric characteristic symbol
Tolerance
Modifier

(c) Feature Control Symbols


Symbol
Tolerance
⊥ A .002
Datum reference
A B .002
Reference to two datums
Modifier applicable to datum
Modifier of Tolerance
⌖ A Ⓜ ⌀.002Ⓜ
Datum reference

(d) Feature Control Symbols with Datum References

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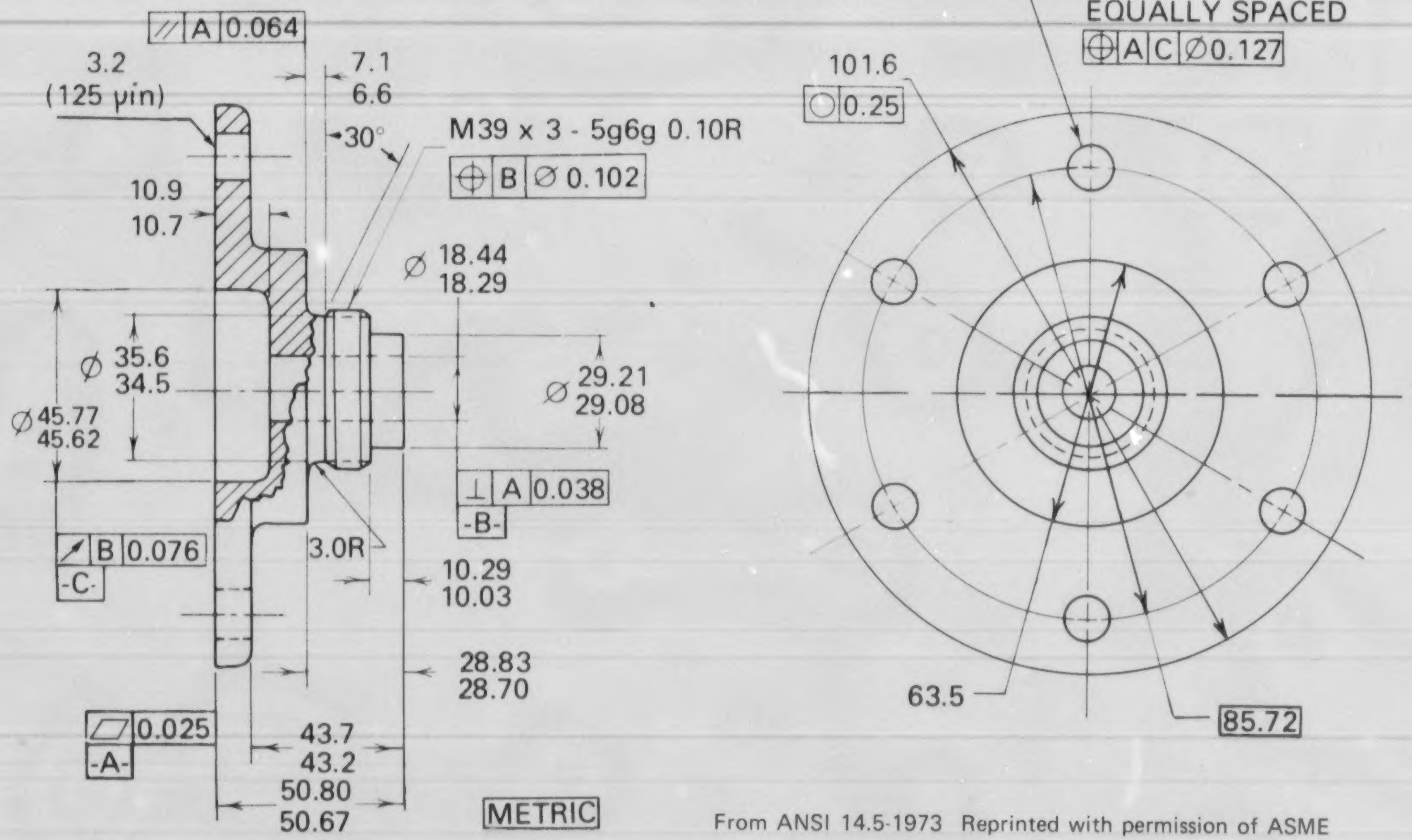
Application of Symbols to Position and Form Tolerance Dimensions


// A 0.064
3.2
(125 μin)
7.1
6.6
30°
M39 x 3 - 5g6g 0.10R
⌖ B ∅ 0.102
10.9
10.7
∅ 18.44
18.29
∅ 35.6
34.5
∅ 45.77
45.62
∅ 29.21
29.08
⊥ A 0.038
-B-
↗ B 0.076
-C-
3.0R
10.29
10.03
28.83
28.70
⏥ 0.025
-A-
43.7
43.2
50.80
50.67
METRIC
7.92 - 8.13 6 HOLES
EQUALLY SPACED
⌖ A C ∅0.127
101.6
○ 0.25
63.5
85.72

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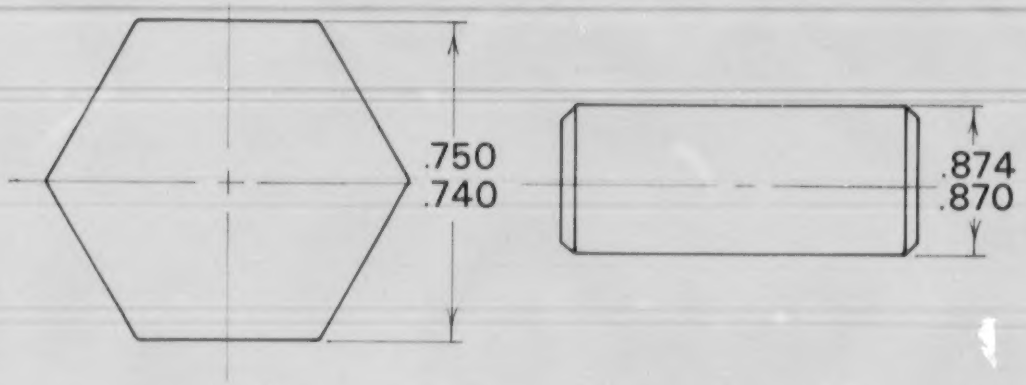
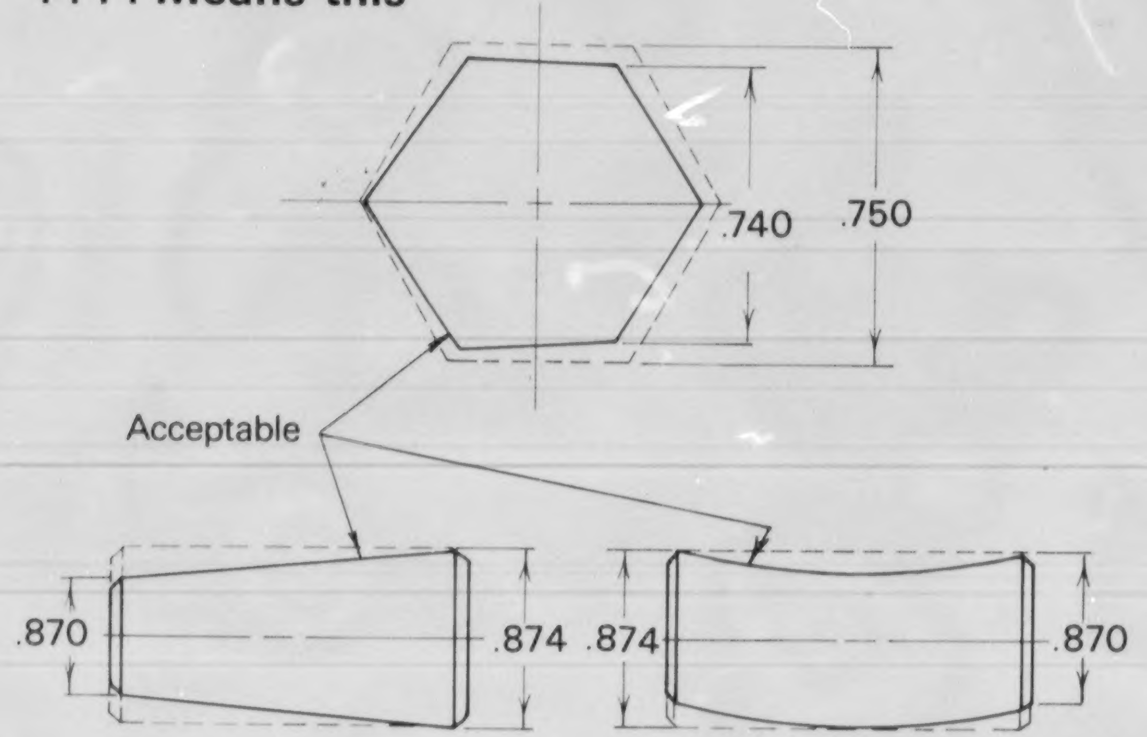
No Specified Tolerance of Form

This on the drawing . . . .


.750
.740
.874
.870

. . . . Means this


.740
.750
Acceptable
.870
.874
.874
.870

(NOTE: Tolerance zone or boundary within which forms may vary when no tolerance of form is given.)

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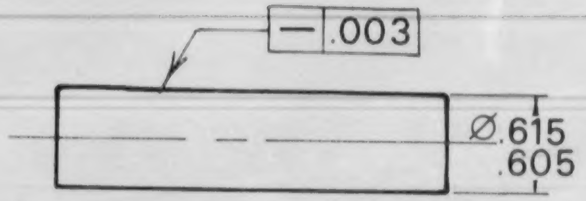
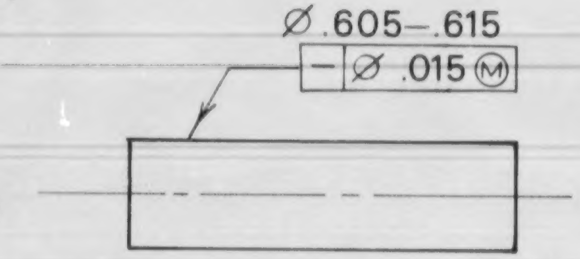
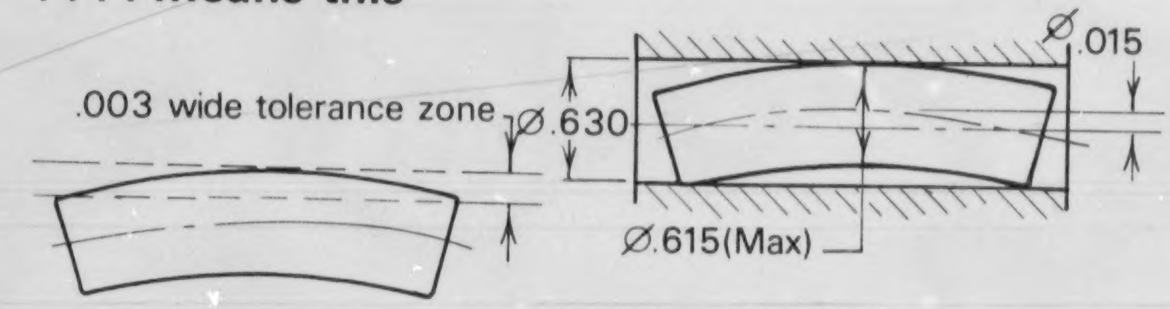
Straightness

This on the drawing . . . .

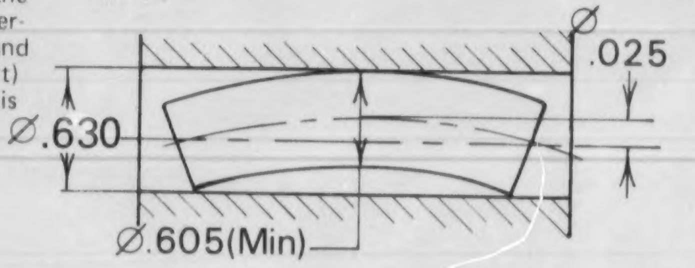

— .003
Ø.615
.605


Ø.605–.615
— Ø .015 Ⓜ

. . . . Means this


.003 wide tolerance zone
Ø.630
Ø.015
Ø.615(Max)

(NOTE: Each longitudinal element of the surface must be within the specified tolerance size of the perfect form at MMC and lie between two parallel lines (.003 apart) where the two lines and the nominal axis share a common plane.)


Ø.630
Ø.025
Ø.605(Min)

(NOTE: Each circular element of the figure must be within the specified tolerance of size. The centerline of the feature must lie within a cylindrical tolerance zone of .015 at MMC. The allowed straightness tolerance increases equal to the amount the feature departs from MMC.)

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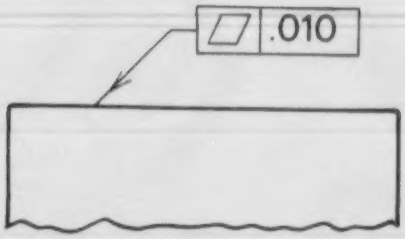
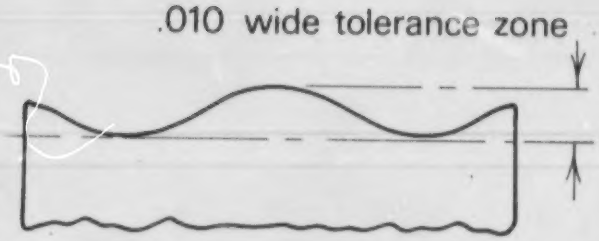
Flatness

This on the drawing . . . .



. . . . Means this


.010 wide tolerance zone

(NOTE: The surface must be within the specified tolerance of size and must lie between two parallel planes .010 apart.)

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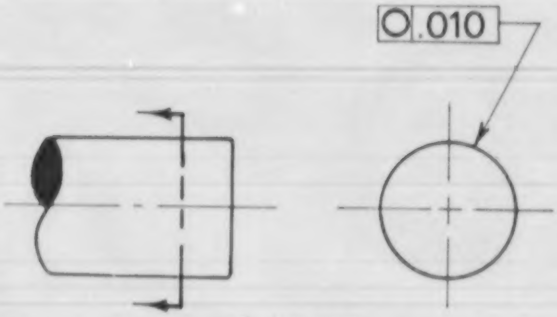
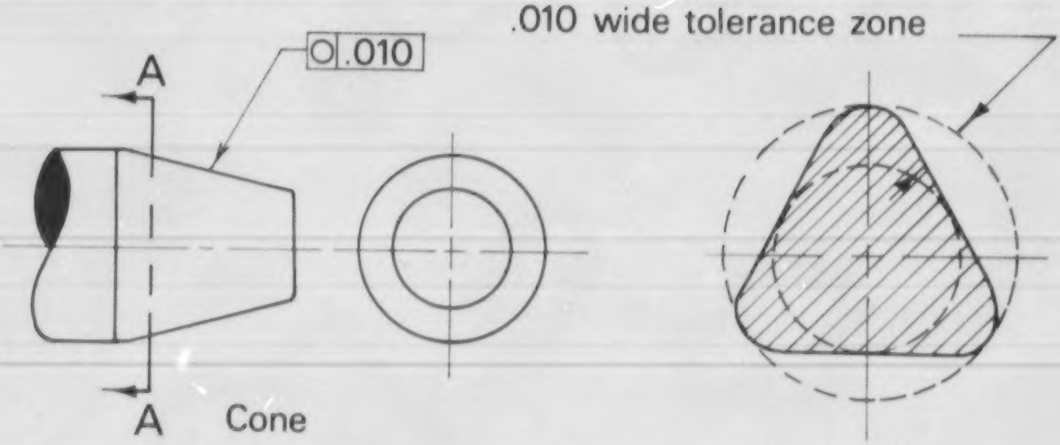
Roundness

This on the drawing . . . .



Cylinder

. . . . Means this



Cone

Section A-A

(NOTE: Each circular element of the surface in any plane perpendicular to a common asix must be within the specified tolerance of size and must lie between two concentric circles -- one having a radius .010 larger than the other.)

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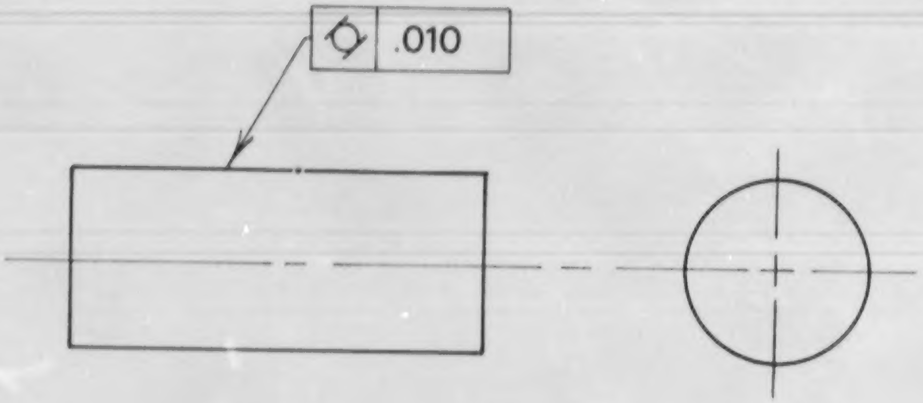
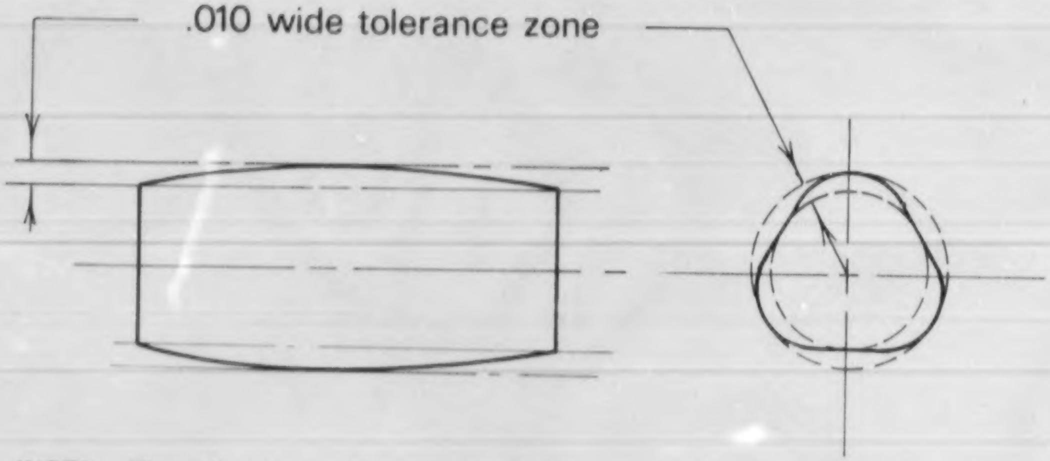
Cylindricity

This on the drawing . . . .



. . . . Means this



(NOTE: The cylindrical surface must be within the specified tolerance of size and must lie between two concentric cylinders -- one having a radius .010 larger than the other.)

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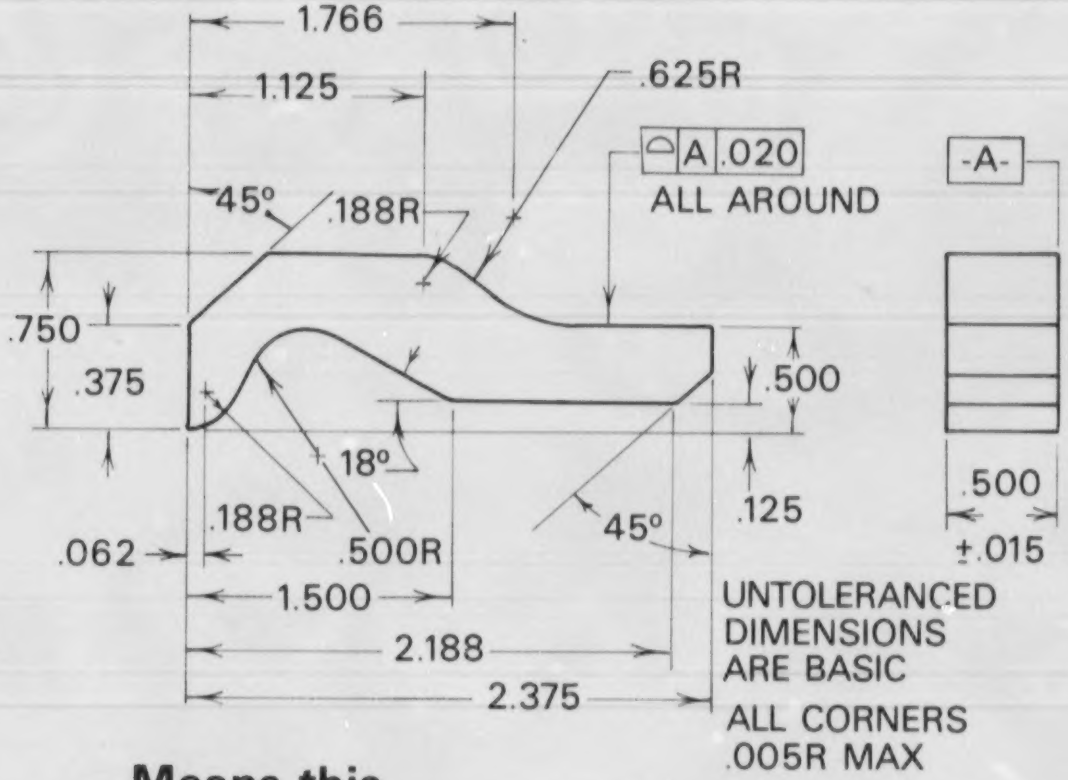
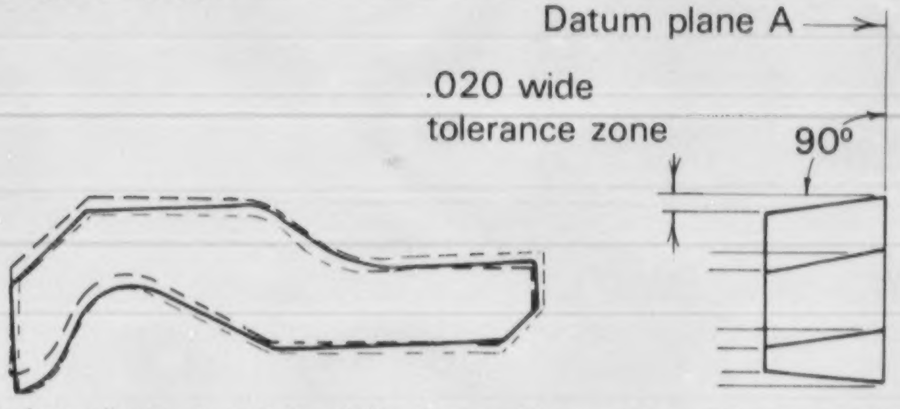
Profile of a Surface

This on the drawing . . . .


1.766
1.125
.625R
⌓ A .020
ALL AROUND
-A-
45°
.188R
.750
.375
.500
18°
.188R
.500R
45°
.125
.500
±.015
.062
1.500
2.188
2.375
UNTOLERANCED DIMENSIONS ARE BASIC
ALL CORNERS .005R MAX

. . . . Means this


Datum plane A
.020 wide tolerance zone
90°

(NOTE: Surfaces all around must lie within two parallel boundaries .020 apart equally disposed about the true profile which are perpendicular to datum plane A. Radii of part corners must not exceed .005 R.)

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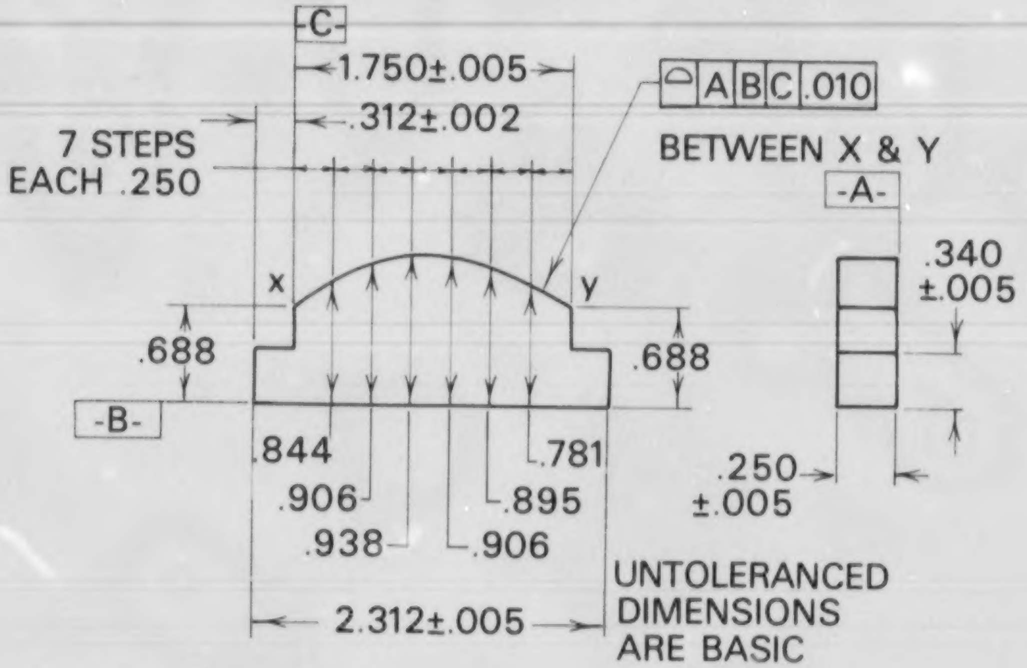
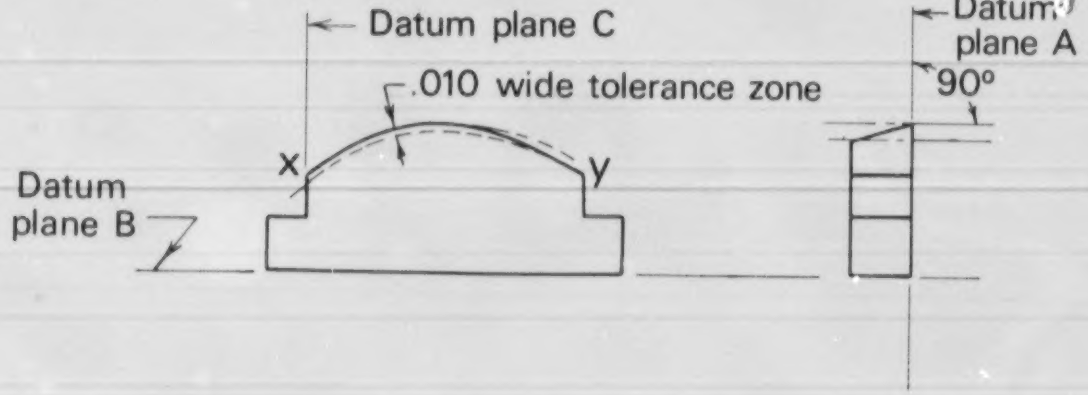
Profile of a Surface Between Points

This on the drawing . . . .


-C-
1.750±.005
.312±.002
7 STEPS
EACH .250
⌓ A B C .010
BETWEEN X & Y
-A-
X
Y
.688
.688
.340
±.005
-B-
.844
.781
.906
.895
.938
.906
.250
±.005
2.312±.005
UNTOLERANCED
DIMENSIONS
ARE BASIC

. . . . Means this


Datum plane C
.010 wide tolerance zone
Datum
plane A
90°
X
Y
Datum
plane B

(NOTE: The surface between points X and Y must lie between the two profile boundaries .010 apart, equally disposed about the true profile, which are perpendicular to datum plane A and positioned with respect to datum planes B and C.)

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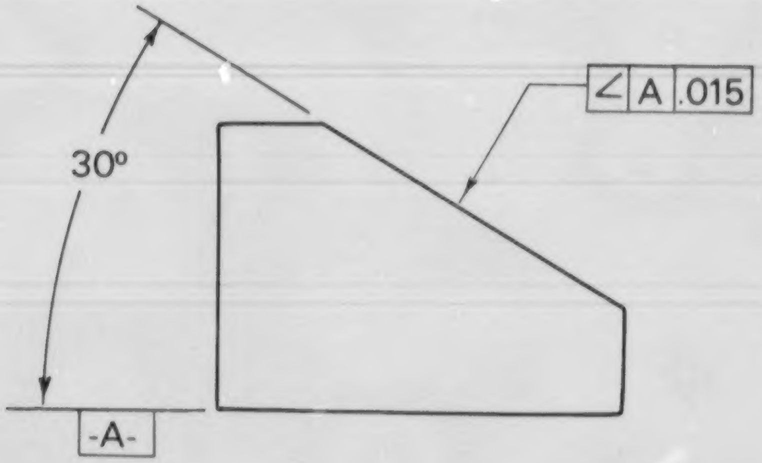
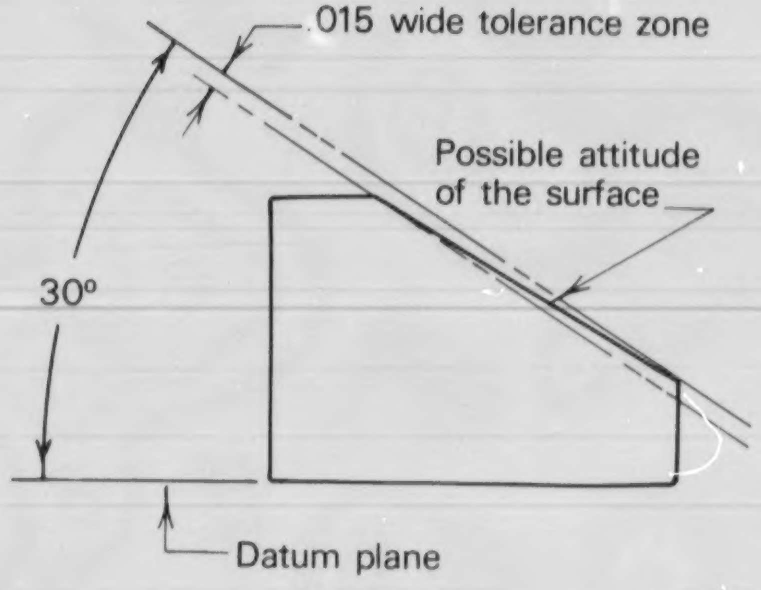
Angularity of a Plane Surface

This on the drawing . . . .



. . . . Means this


.015 wide tolerance zone
Possible attitude of the surface
30°
Datum plane

(NOTE: The surface must be within the specified tolerance of size and must lie between two parallel planes .015 apart which are inclined at 30° to the datum plane.)

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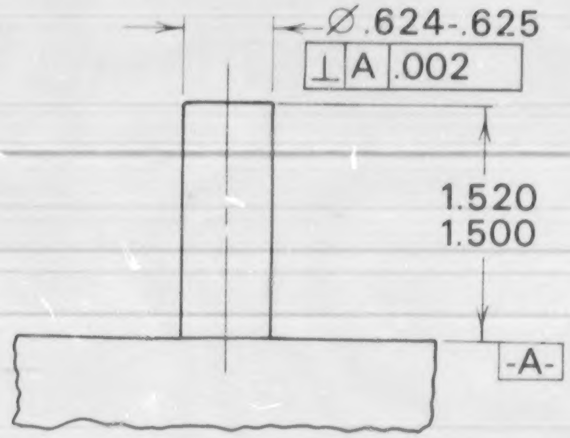
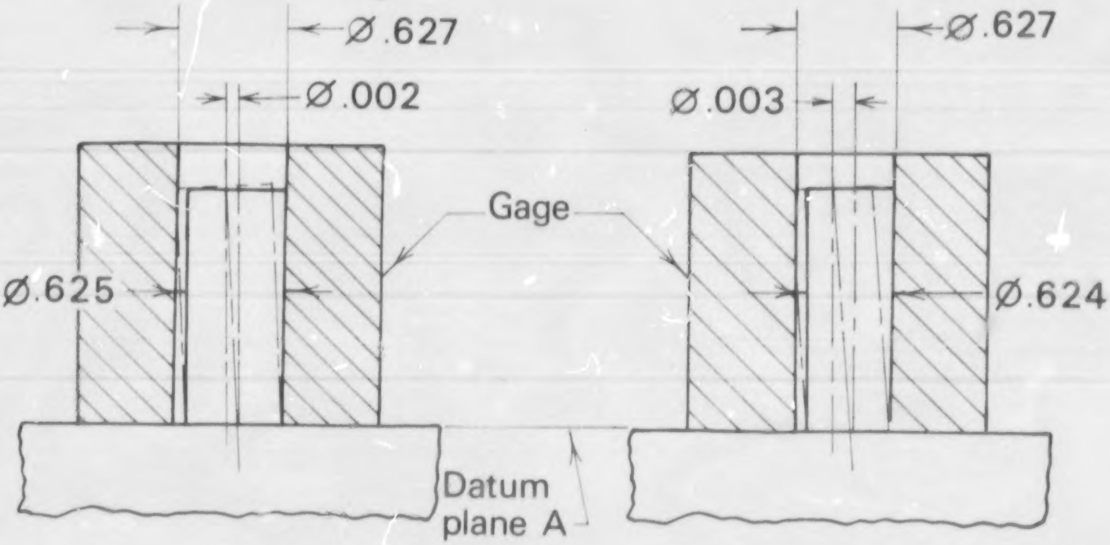
Perpendicularity

This on the drawing . . . .


Ø.624-.625
⊥ A .002
1.520
1.500
-A-

. . . . Means this


Ø.627
Ø.002
Ø.003
Ø.627
Gage
Ø.625
Ø.624
Datum plane A

(NOTE: The feature axis must be within the specified tolerance of location. Where the feature is at MMC (.625), the maximum perpendicularity tolerance is .002 diameter. Where the feature departs from its MMC size, an increase in the perpendicularity tolerance is allowed which is equal to the amount of such departure.)

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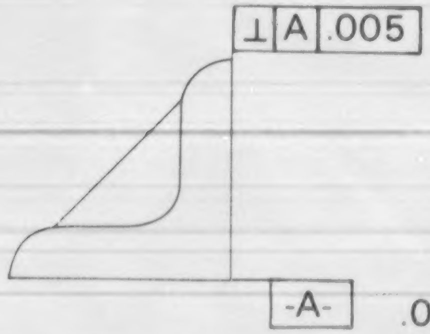
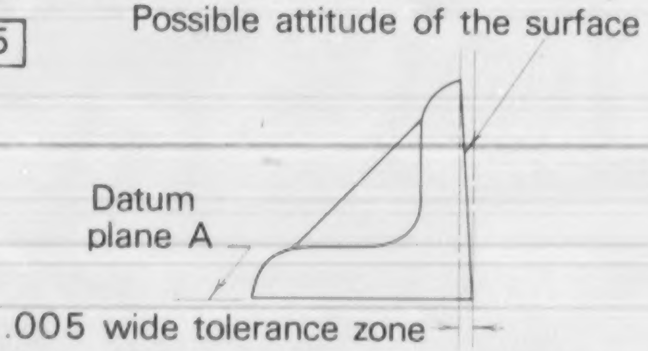
Perpendicularity
(Continued)

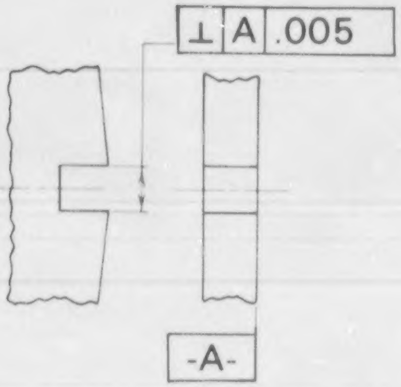
This on the drawing . . . . . . Means this

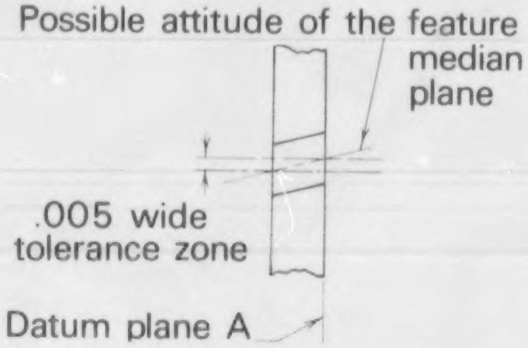



Possible attitude of the surface
Datum plane A
.005 wide tolerance zone

For a Plane Surface

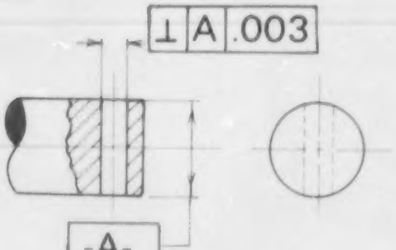
(NOTE: The surface must be within the specified tolerance of size and must lie between two parallel planes .005 apart which are perpendicular to the datum plane.)

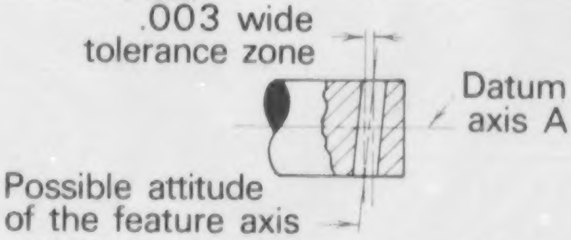



Possible attitude of the feature median plane
.005 wide tolerance zone
Datum plane A

For a Median Plane

(NOTE: The feature median plane must be within the specified tolerance of location and must lie between two parallel planes .005 apart, regardless of feature size, which are perpendicular to the datum plane.)




.003 wide tolerance zone
Datum axis A
Possible attitude of the feature axis

For an Axis

(NOTE: The feature axis must be within the specified tolerance of location and must lie between two planes .003 apart, regardless of feature size, which are perpendicular to the datum axis.)

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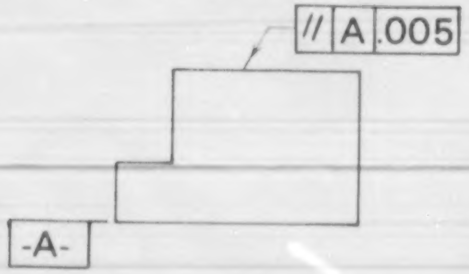
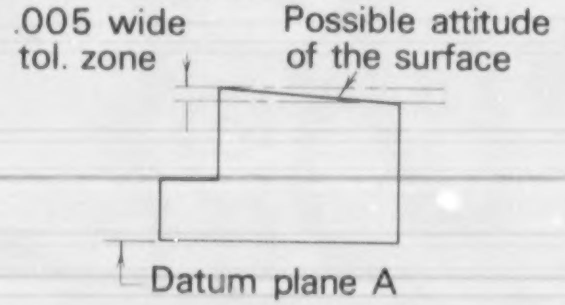
Parallelism

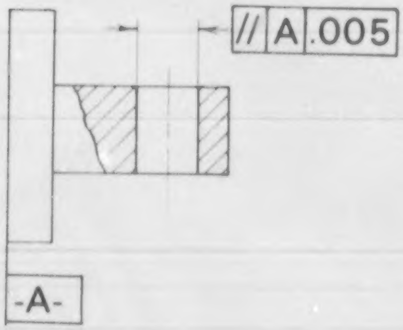
This on the drawing . . . . . . Means this



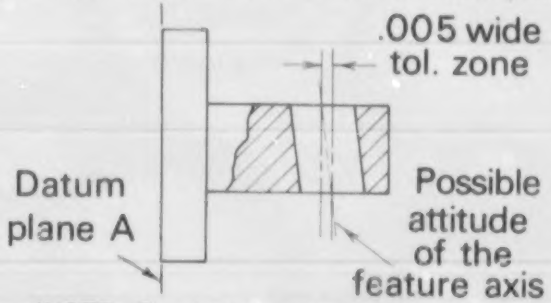
For a Plane Surface


.005 wide tol. zone
Possible attitude of the surface
Datum plane A

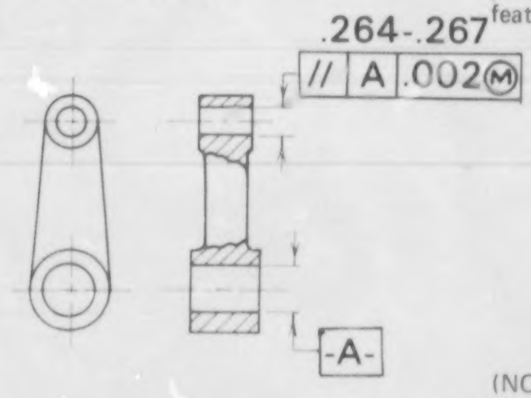
(NOTE: The surface must be within the specified tolerance of size and must lie between two planes .005 apart which are parallel to the datum plane.)



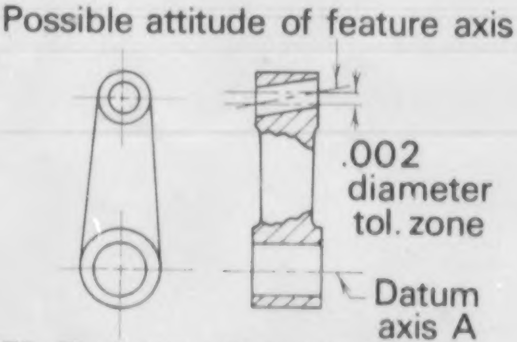
For an Axis


.005 wide tol. zone
Datum plane A
Possible attitude of the feature axis

(NOTE: The feature axis must be within the specified tolerance of location and must lie between two planes .005 apart which are parallel to the datum plane, regardless of feature size.)


.264-.267
// A .002 Ⓜ
-A-

For an Axis - Feature at MMC


Possible attitude of feature axis
.002 diameter tol. zone
Datum axis A

(NOTE: The feature axis must be within the specified tolerance of location. Where the feature is at maximum material condition (.264), the maximum parallelism tolerance is .002 diameter. Where the feature departs from its MMC size, an increase in the parallelism tolerance is allowed which is equal to the amount of such departure.)

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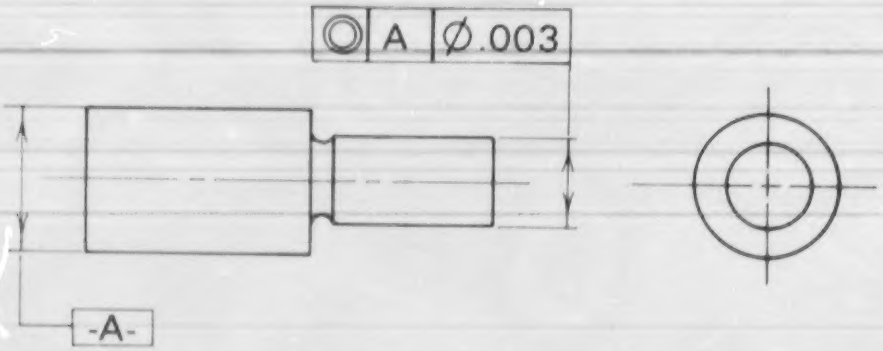
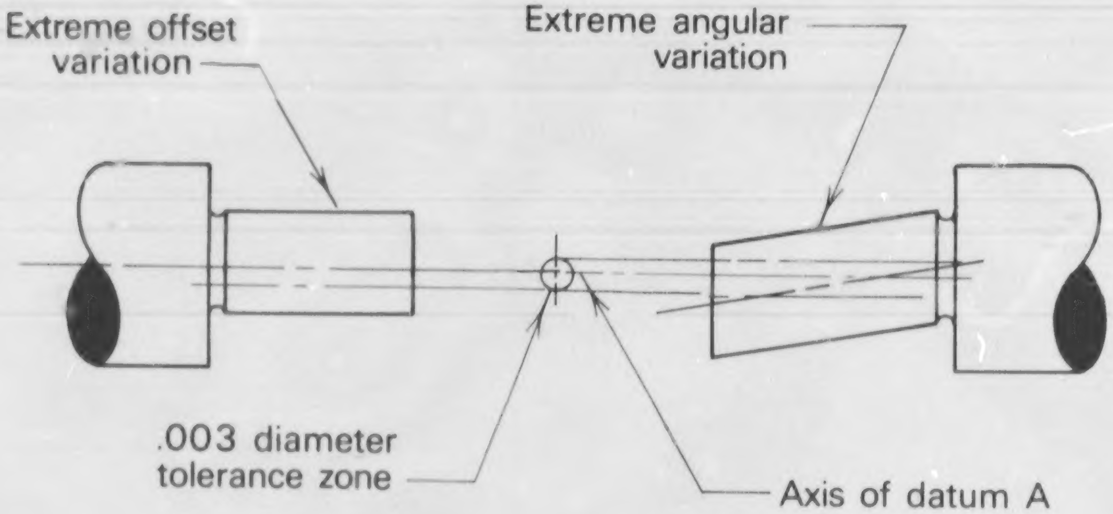
Concentricity

This on the drawing . . . .



. . . . Means this


Extreme offset variation
Extreme angular variation
.003 diameter tolerance zone
Axis of datum A

(NOTE: The feature axis must be within a cylindrical zone whose diameter is equal to the concentricity tolerance and whose axis coincides with the datum axis.)

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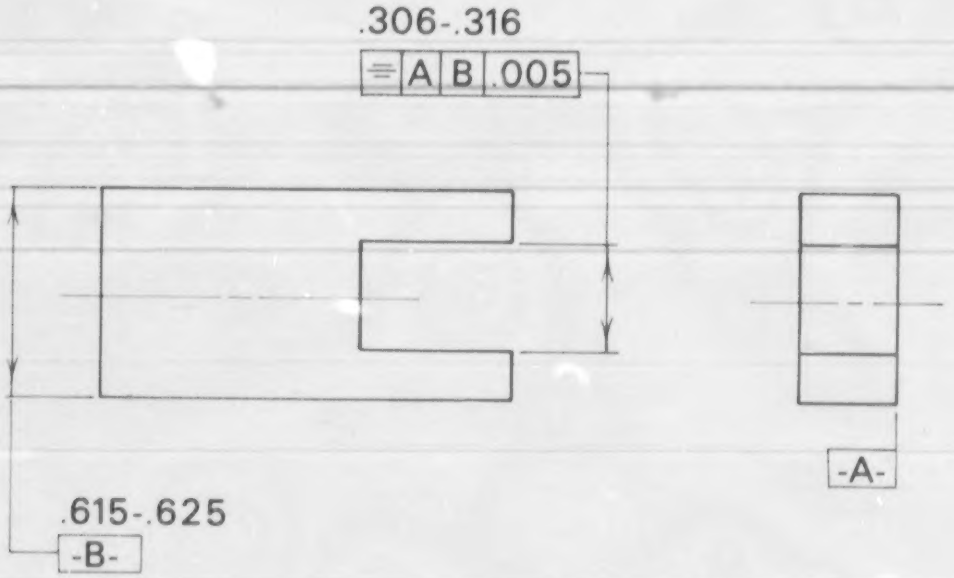
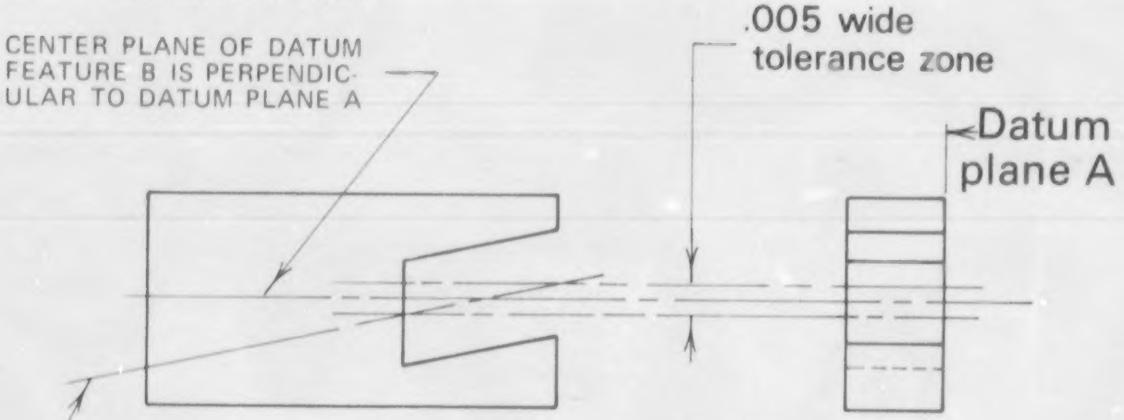
Symmetry

This on the drawing . . . .


.306-.316
⌯ A B .005
.615-.625
-B-
-A-

. . . . Means this


.005 wide tolerance zone
Datum plane A

CENTER PLANE OF DATUM FEATURE B IS PERPENDICULAR TO DATUM PLANE A

CENTER PLANE OF SLOT MUST LIE BETWEEN PARALLEL PLANES .005 APART, REGARDLESS OF FEATURE SIZE, WHICH ARE EQUALLY DISPOSED ABOUT THE CENTER PLANE OF DATUM B

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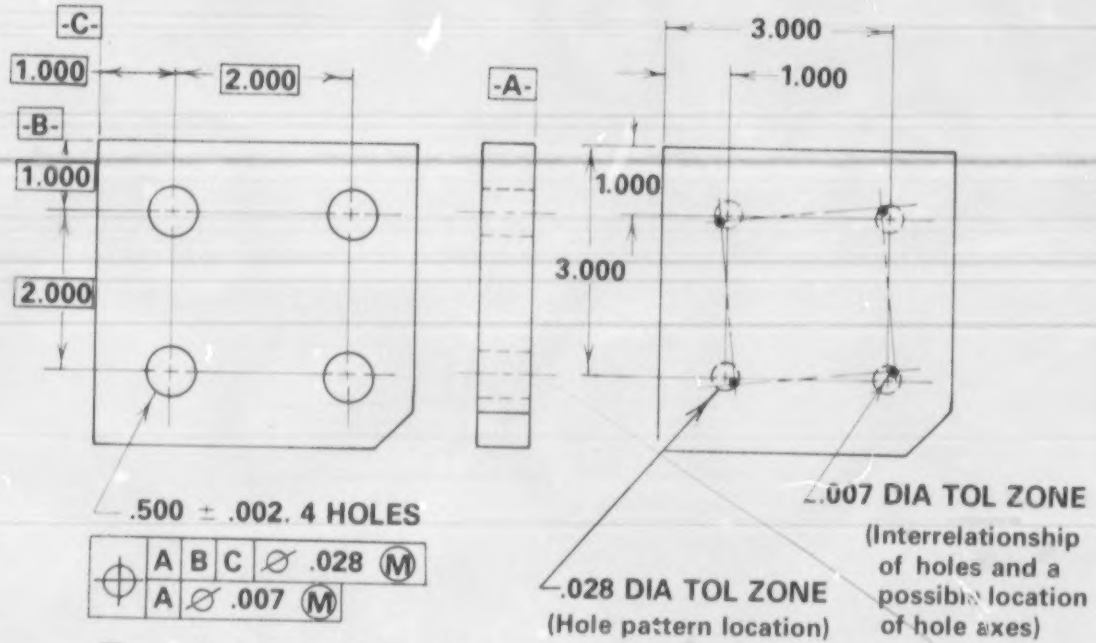
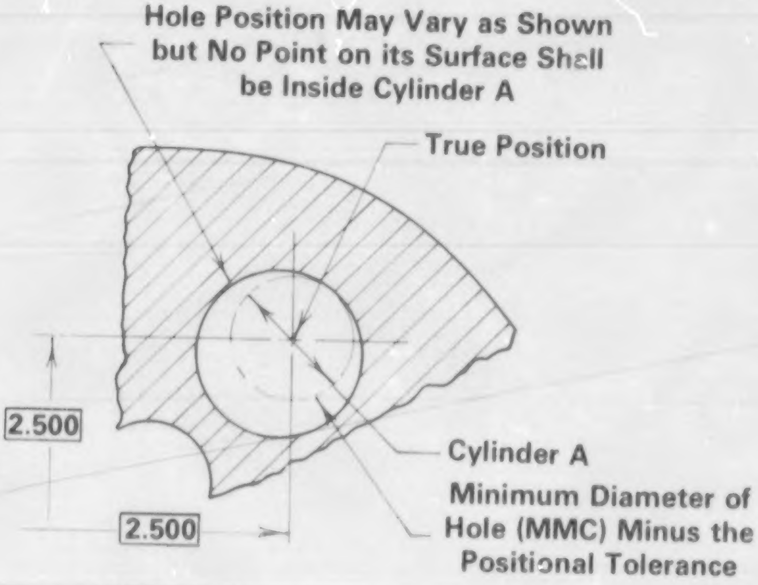
Positional Tolerancing


-C-
1.000
2.000
-B-
1.000
2.000
-A-
3.000
1.000
1.000
3.000
.500 ± .002. 4 HOLES
⌖ | A | B | C | ⌀ .028 Ⓜ
A | ⌀ .007 Ⓜ
.028 DIA TOL ZONE
(Hole pattern location)
.007 DIA TOL ZONE
(Interrelationship of holes and a possible location of hole axes)

Positional Tolerance Dimensioning


Hole Position May Vary as Shown but No Point on its Surface Shall be Inside Cylinder A
True Position
2.500
2.500
Cylinder A
Minimum Diameter of Hole (MMC) Minus the Positional Tolerance

Positional Tolerance Interpretation

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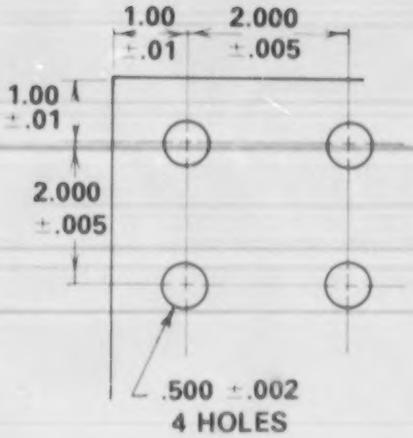
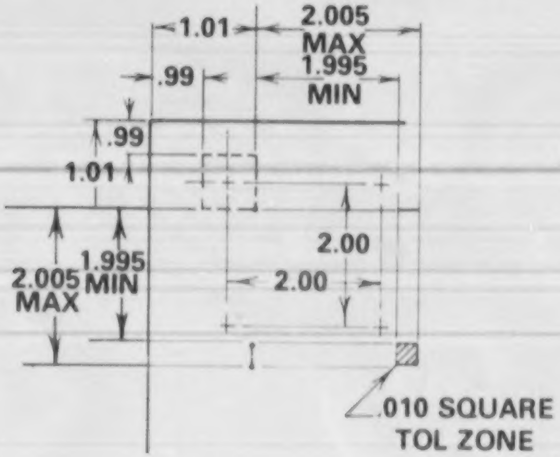
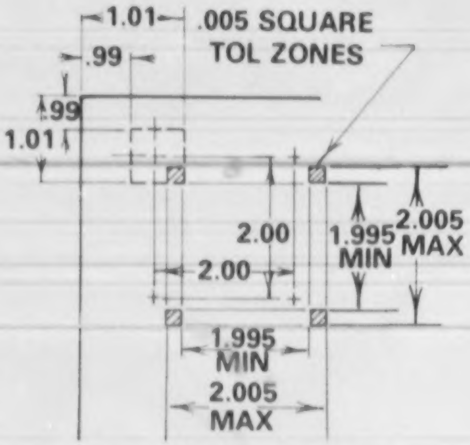
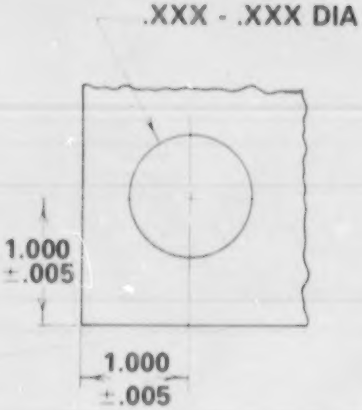
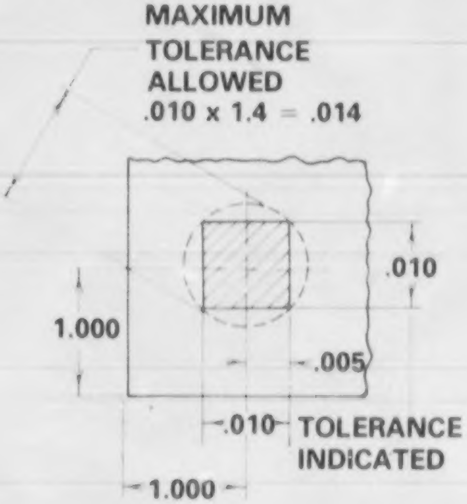
Tolerance Zones


1.00
±.01
2.000
±.005
1.00
±.01
2.000
±.005
.500 ±.002
4 HOLES


1.01
2.005
MAX
.99
1.995
MIN
.99
1.01
2.00
2.00
2.005
MAX
1.995
MIN
.010 SQUARE
TOL ZONE


1.01
.005 SQUARE
TOL ZONES
.99
.99
1.01
2.00
1.995
MIN
2.005
MAX
2.00
1.995
MIN
2.005
MAX


.XXX - .XXX DIA
1.000
±.005
1.000
±.005


MAXIMUM
TOLERANCE
ALLOWED
.010 x 1.4 = .014
.010
1.000
.005
.010
TOLERANCE
INDICATED
1.000

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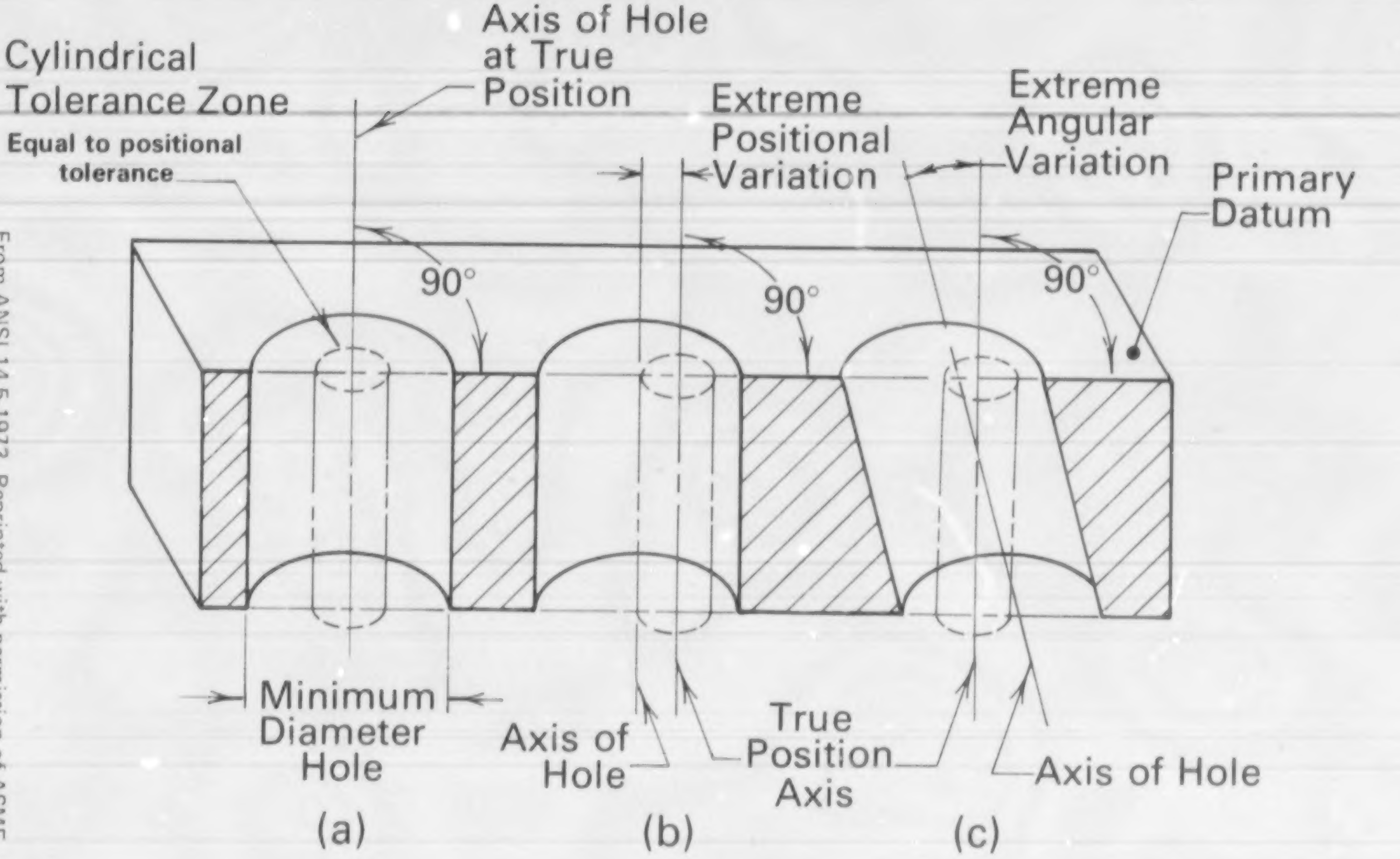
Cylindrical Tolerance Zones


Cylindrical Tolerance Zone
Equal to positional tolerance
Axis of Hole at True Position
Extreme Positional Variation
Extreme Angular Variation
Primary Datum
90°
90°
90°
Minimum Diameter Hole
Axis of Hole
True Position Axis
Axis of Hole
(a)
(b)
(c)

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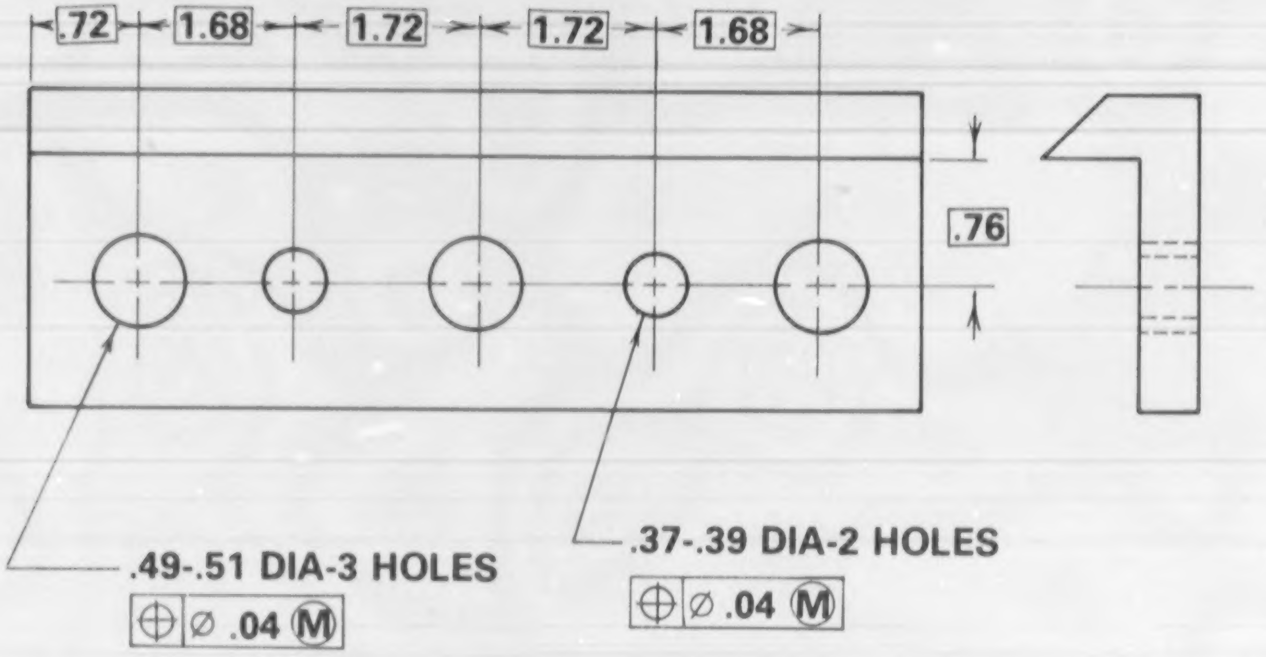
No Tolerance Accumulation


.72
1.68
1.72
1.72
1.68
.76
.49-.51 DIA-3 HOLES
⌖ Ø .04 Ⓜ
.37-.39 DIA-2 HOLES
⌖ Ø .04 Ⓜ

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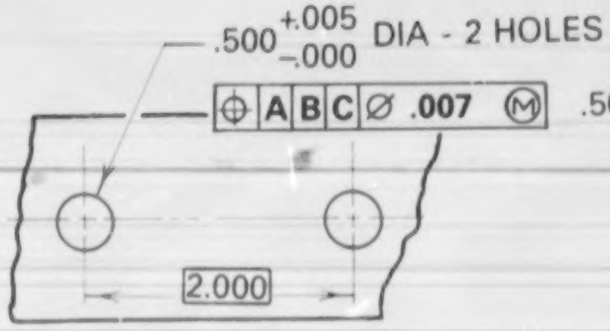
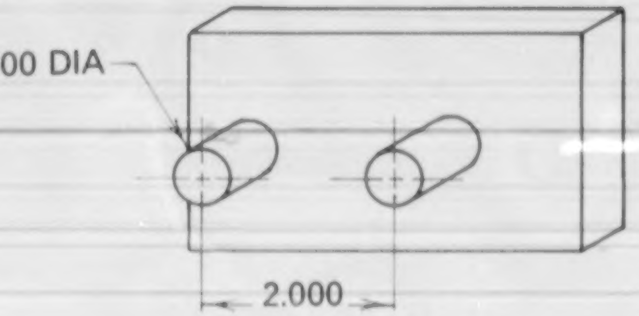
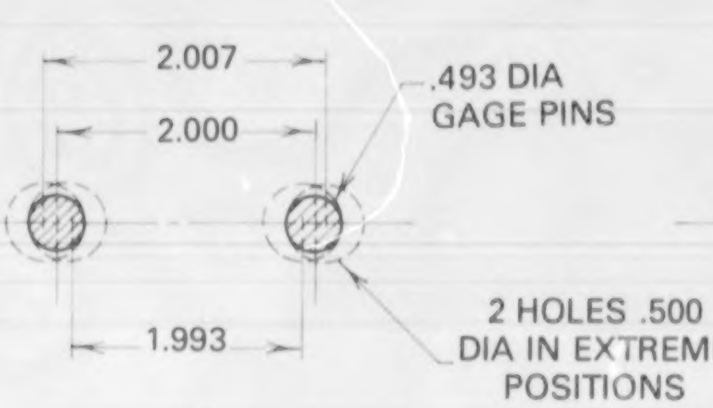
Maximum and Least Material Conditions


.500 +.005 −.000 DIA - 2 HOLES
⊕ A B C ∅ .007 Ⓜ
2.000

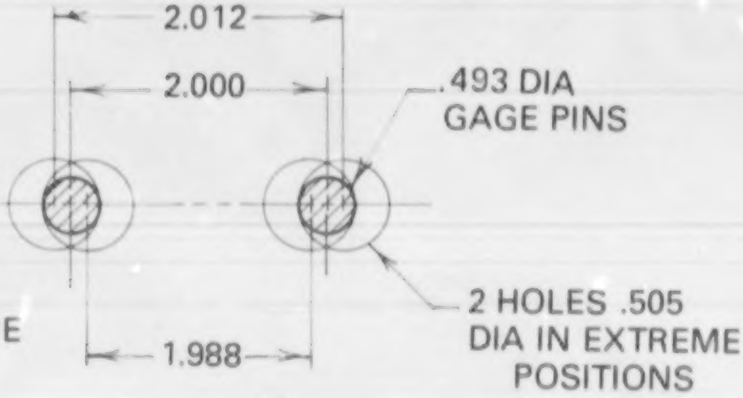
(a)


.500 DIA
2.000

(b)


2.007
2.000
.493 DIA GAGE PINS
1.993
2 HOLES .500 DIA IN EXTREME POSITIONS

(c)


2.012
2.000
.493 DIA GAGE PINS
1.988
2 HOLES .505 DIA IN EXTREME POSITIONS

(d)

(NOTE: When holes are large, an extra tolerance causes 2.007 to increase to 2.012 and 1.993 to 1.988. The extra positional tolerance is acceptable and desirable. When not specified, MMC applies to positional tolerances and related datums.)

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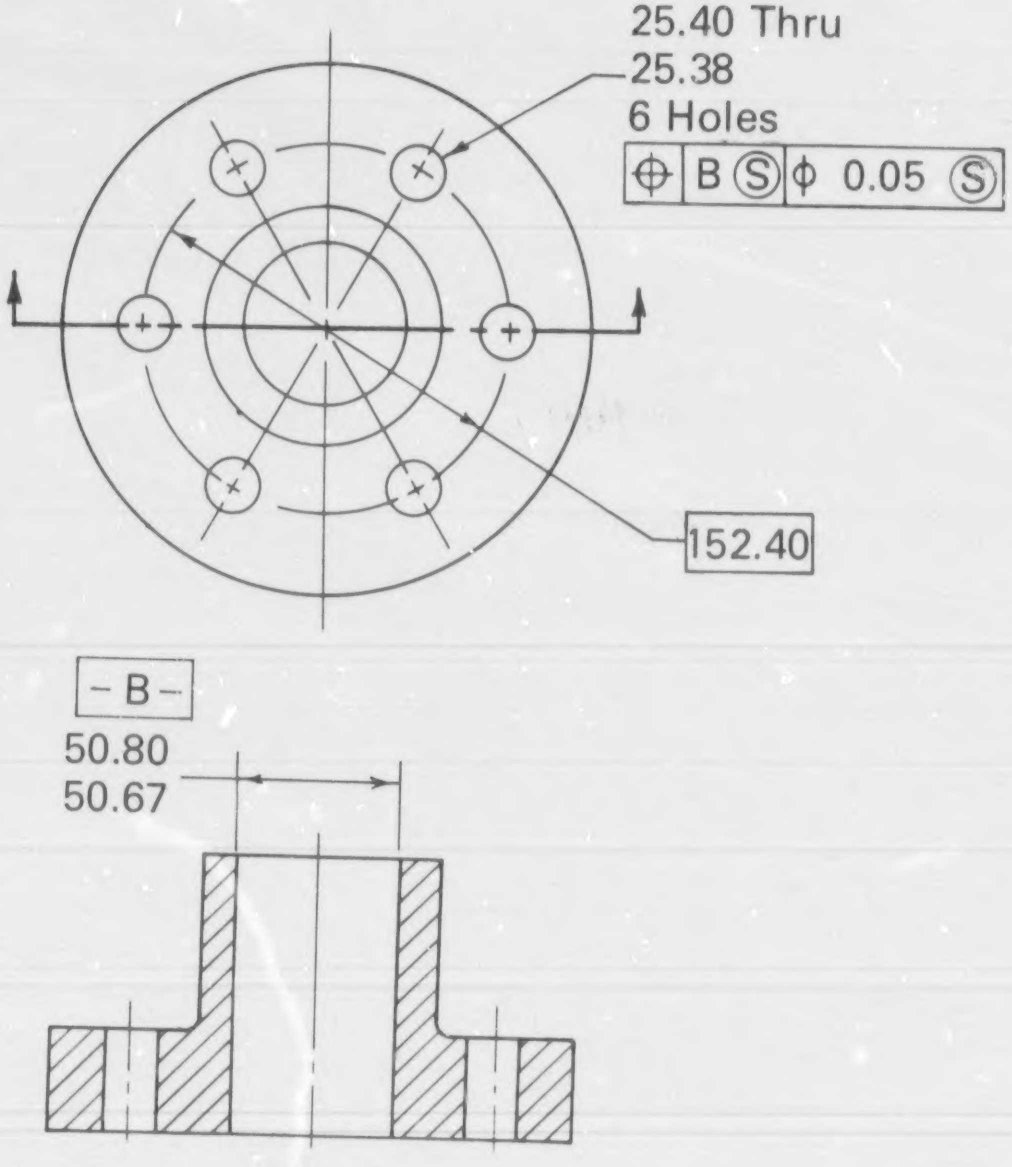
272

Regardless of Feature Size


25.40 Thru
25.38
6 Holes
⊕ | B Ⓢ | ϕ 0.05 Ⓢ
152.40
- B -
50.80
50.67

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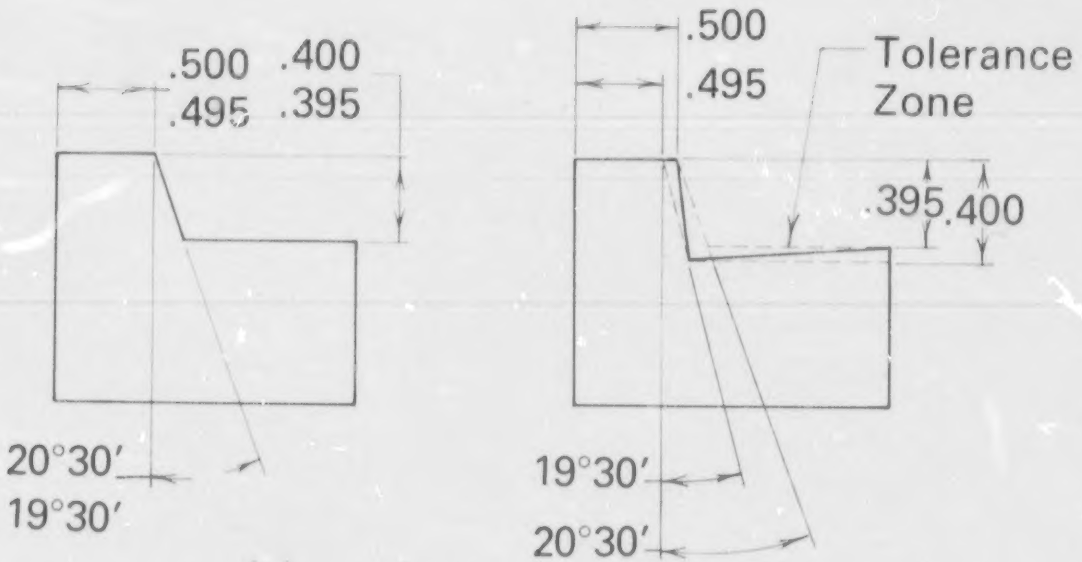
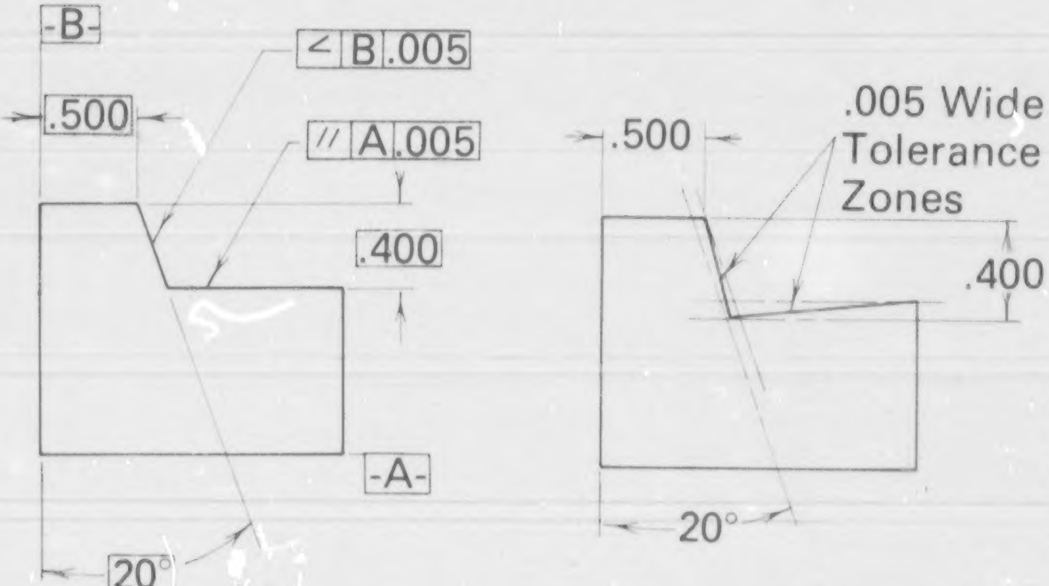
Angular Tolerances


.500
.495
.400
.395
20°30′
19°30′
.500
.495
Tolerance Zone
.395
.400
19°30′
20°30′

(a) (b)

Bilateral Angular Tolerances


-B-
∠ B .005
.500
// A .005
.400
-A-
20°
.500
.005 Wide Tolerance Zones
.400
20°

(c) (d)

Basic Angular Tolerances

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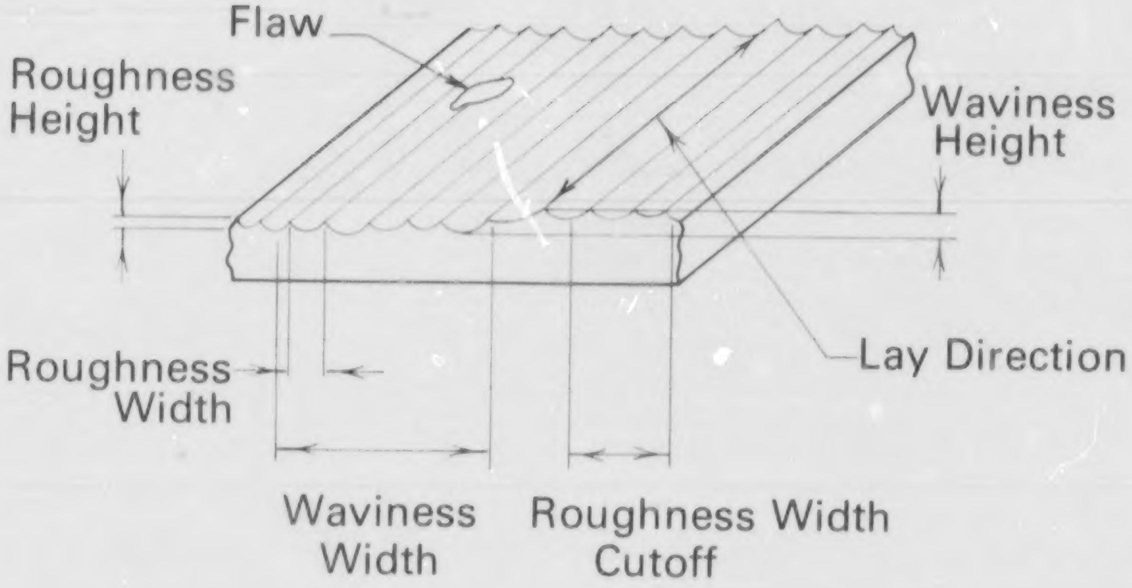
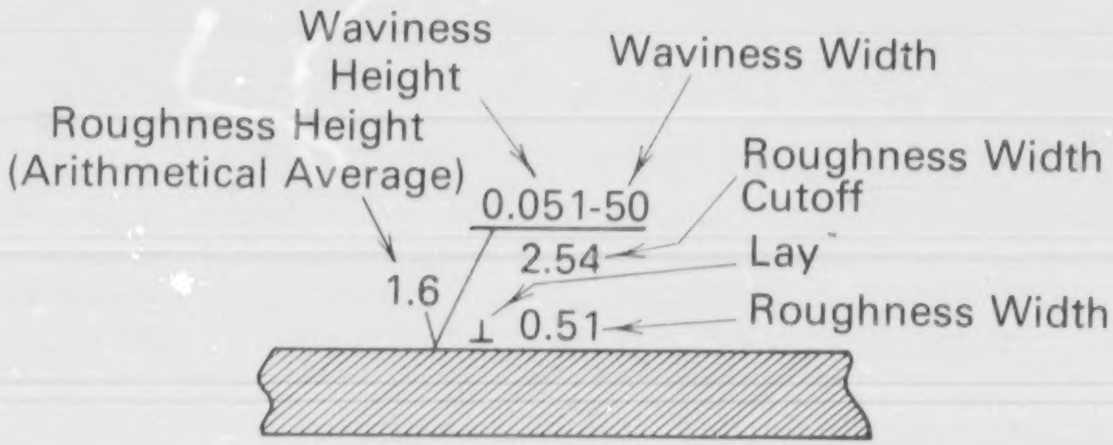
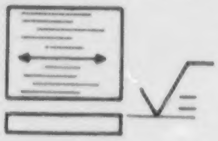
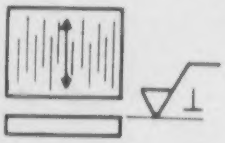
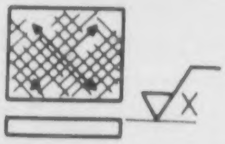
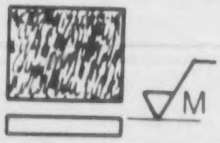
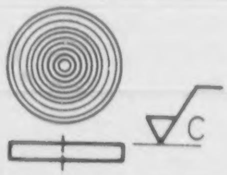
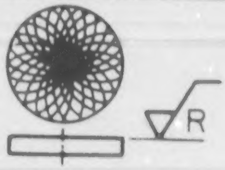
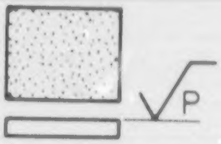
Surface Quality Symbol


Flaw
Roughness Height
Waviness Height
Lay Direction
Roughness Width
Waviness Width
Roughness Width Cutoff


Waviness Height
Waviness Width
Roughness Height (Arithmetical Average)
0.051-50
Roughness Width Cutoff
2.54
Lay
1.6
⊥ 0.51
Roughness Width

Lay Symbols

Lay Symbol	Meaning	Example Showing Direction of Tool Marks
=	Lay approximately parallel to the line representing the surface to which the symbol is applied.	
⊥	Lay approximately perpendicular to the line representing the surface to which the symbol is applied.	
X	Lay angular in both directions to line representing the surface to which the symbol is applied.	
M	Lay multidirectional.	
C	Lay approximately circular relative to the center of the surface to which the symbol is applied.	
R	Lay approximately radial relative to the center of the surface to which the symbol is applied.	
P[3]	Lay particulate, non-directional, or protuberant.	

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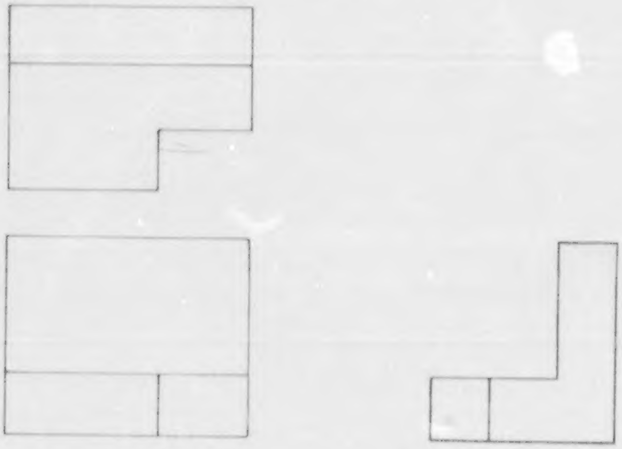
DIMENSIONING AND TOLERANCING
UNIT V

ASSIGNMENT SHEET #1--DIMENSION AN OBJECT COMPLETELY

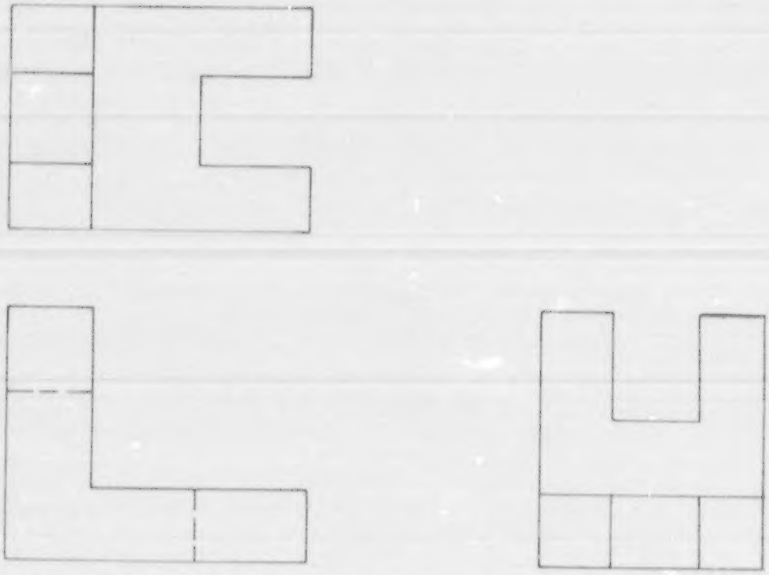
Directions: With drafting tools and machine, dimension the objects below using proper dimensioning rules and techniques.

Problems:

A. Full size - inch system - fractions

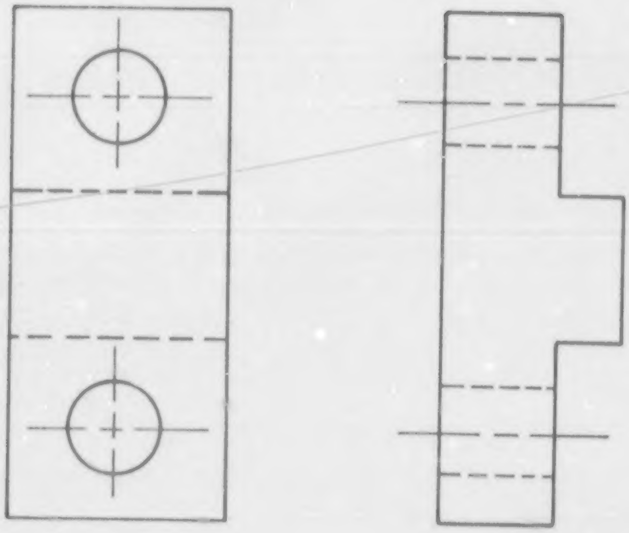


B. Half size - metric system



ASSIGNMENT SHEET #1

C. 1/4" = 1" - inch system - decimal



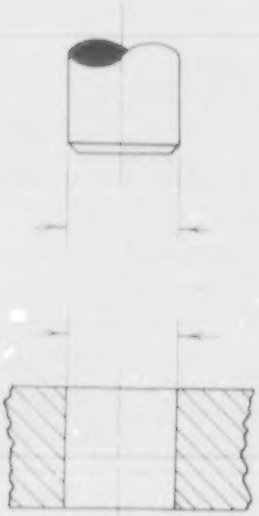
DIMENSIONING AND TOLERANCING
UNIT V

ASSIGNMENT SHEET #2--CALCULATE AND DIMENSION CLEARANCE FIT TOLERANCES USING STANDARD FIT TABLES

Directions: Calculate and dimension the following clearance fit tolerances using standard fit tables.

Problems:

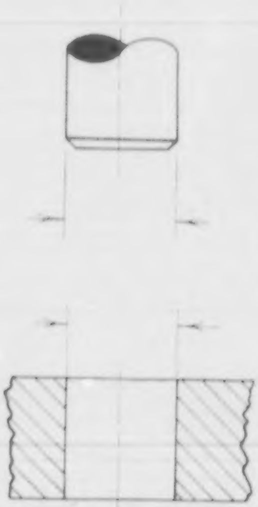
A. Inch system using ANSI B 4.1 -1967, R 1974



Fit RC 4

Basic Size 1.00

Check fit

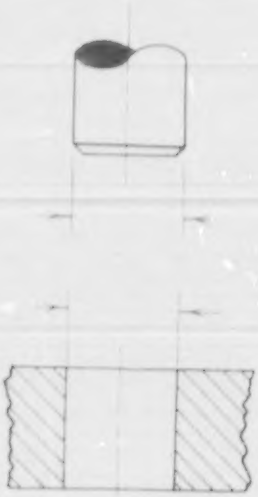


Fit RC 2

Basic Size 2.50

Check fit

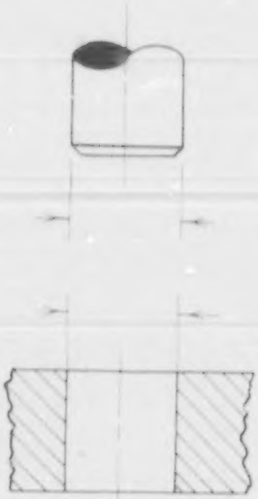
B. Metric system using ANSI B 4.2 -1978



Fit H7/g6

Basic Size 40

Check fit



Fit D9/h9

Basic Size 2.5

Check fit

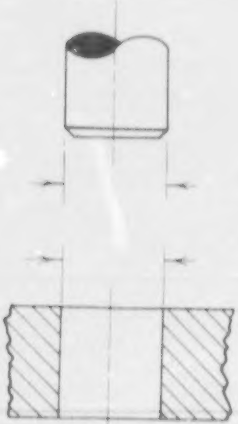
DIMENSIONING AND TOLERANCING
UNIT V

ASSIGNMENT SHEET #3--CALCULATE AND DIMENSION INTERFERENCE FIT TOLERANCES USING STANDARD FIT TABLES

Directions: Calculate and dimension the following interference fit tolerances using standard tables.

Problems:

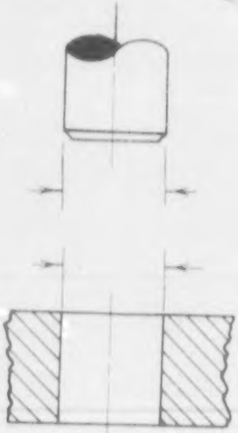
A. Inch system using ANSI B 4.1 -1967, R 1974



Fit FN 4

Basic Size 3.00

Check fit

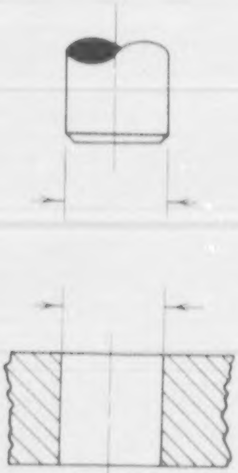


Fit LN 2

Basic Size .5

Check fit

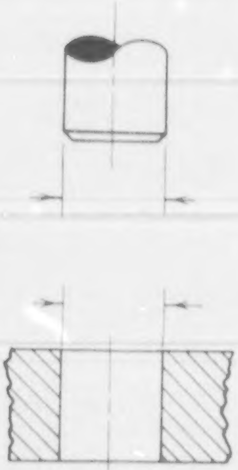
B. Metric system using ANSI B 4.2 -1978



Fit U7/h6

Basic Size 10

Check fit



Fit P7/h6

Basic Size 1.2

Check fit

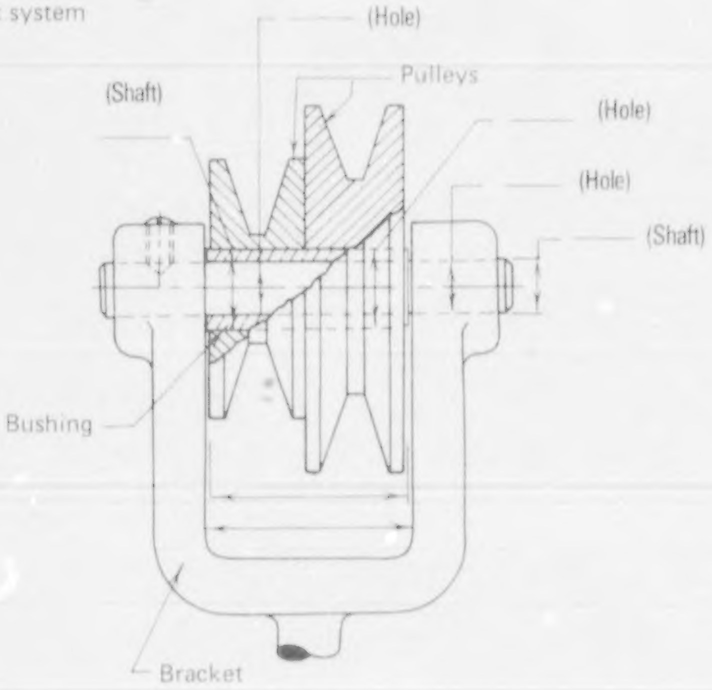
DIMENSIONING AND TOLERANCING
UNIT V

ASSIGNMENT SHEET #4–CALCULATE AND ASSIGN TOLERANCES TO MATING PARTS USING STANDARD FIT TABLES

Directions: Calculate and assign tolerances to mating parts using standard fit tables for the pulley assembly below.

Problems:

A. Metric system



Specifications

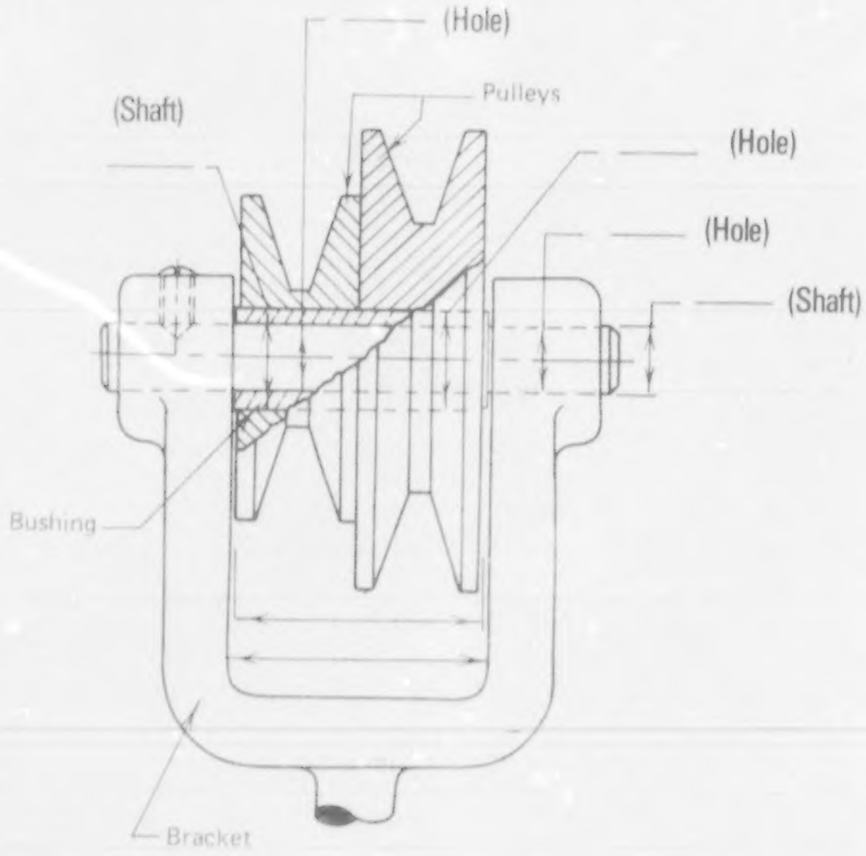
SHAFT-BRACKET FIT 12mm Nominal diameter Fit D9/h9	SHAFT-BUSHING FIT 12mm Nominal diameter Fit F8/h9
BUSHING-PULLEY FIT 20mm Nominal diameter Fit H7/p6	BUSHING-BRACKET FIT 50mm Nominal length Fit H11/c11

Show calculations below

SHAFT-BRACKET	SHAFT-BUSHING
BUSHING-PULLEY	BUSHING-BRACKET

ASSIGNMENT SHEET #4

B. Inch system


(Hole)
Pulleys
(Shaft)
(Hole)
(Hole)
(Shaft)
Bushing
Bracket

Specifications

SHAFT-BRACKET FIT	SHAFT-BUSHING FIT
75 Nominal diameter Fit RC7	.75 Nominal diameter Fit RC 4
BUSHING-PULLEY FIT	**BUSHING-BRACKET FIT**
1.25 Nominal diameter Fit LN1	3 Nominal length Fit RC8

Show calculations below

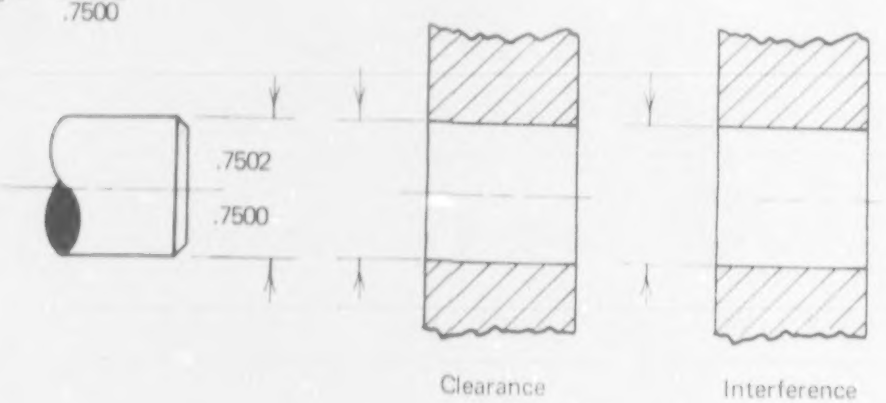
SHAFT-BRACKET	SHAFT-BUSHING
BUSHING-PULLEY	BUSHING-BRACKET

DIMENSIONING AND TOLERANCING
UNIT V

ASSIGNMENT SHEET #5-CALCULATE AND DIMENSION HOLE SIZE LIMITS FOR STANDARD DOWELS

Directions: Calculate and dimension hole size limits for standard dowels using basic shaft system. You should use the appropriate tolerance tables for the following problems.

Dowel limits = $\frac{.7502}{.7500}$



Problems:

A. For a sliding fit with limits of possible clearance from .0003-.0012

B. For an interference fit with limits of interference from .0006-.0019

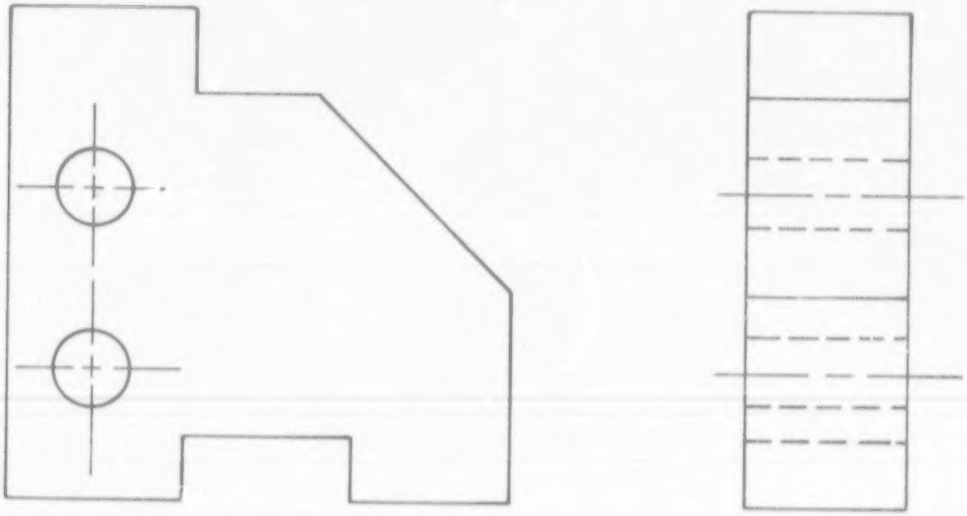
DIMENSIONING AND TOLERANCING
UNIT V

ASSIGNMENT SHEET #6–DIMENSION AN OBJECT USING POSITION AND FORM TOLERANCES

Directions: Dimension an object using position and form tolerances to completely describe it.

(NOTE: Instructor or student may select datums as assigned.)

Problem:



DIMENSIONING AND TOLERANCING
UNIT V

ASSIGNMENT SHEET #7–DETERMINE RANGES OF MOTION OF LIMBS AND SPACES REQUIRED FOR A PERSON

Directions: With the anthropometric data included at the end of this assignment sheet, solve the following problems by using the examples provided as guidelines.

Example #1: Find the width of the head of an adult in the 50 percentile group

a. Go to anthropometric data–Standing adult male

b. Go to 50 percentile drawing of man on chart

c. Locate head and read dimension above it

d. Answer 6.1"

Example #2: Find the reach radius of 50 percentile male

a. Go to anthropometric data–Adult male, seated at console

b. Go to view of man showing his reach radius

c. The reach radius is shown as:

30.7
28.5
26.5

d. The first number 30.7 is for the 97.5 percentile, the 28.5 is for the 50 percentile, and the 26.5 is for the 2.5 percentile

e. Answer 28.5"

Problems:

A. Find the width of the shoulders of a 97.5 percentile adult male.

____

ASSIGNMENT SHEET #7

B. Find the height of a 50 percentile adult female.

____

C. Find the total visual limit in degrees from up to down.

____

D. Find the maximum cylinder hand grasp for a 97.5 percentile adult male.

____

E. Find the average hand breadth of an 11 year-old child.

____

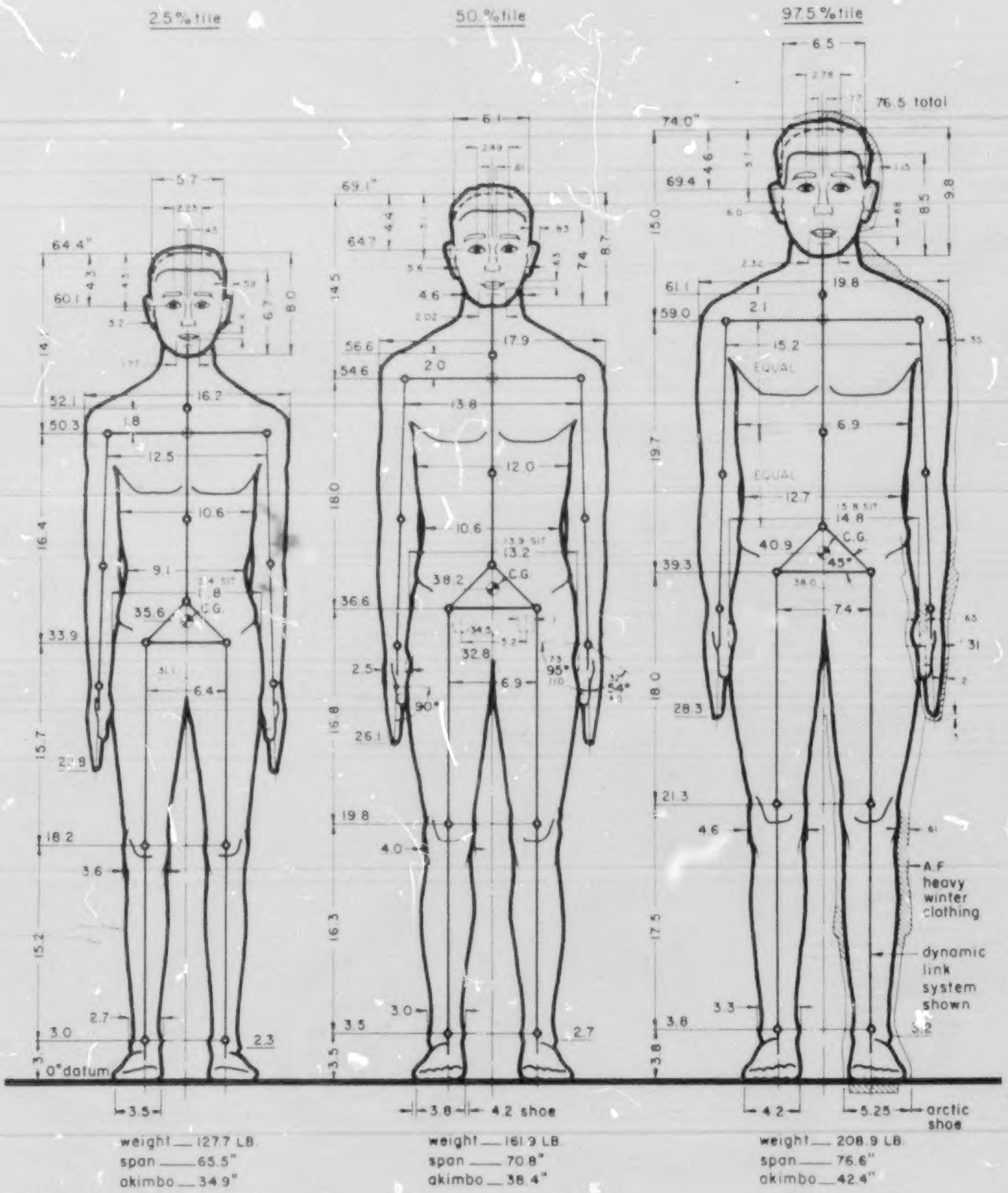
F. Find the average thumb length of a 50 percentile woman.

____

ASSIGNMENT SHEET #7

ANTHROPOMETRIC DATA — STANDING ADULT MALE

ACCOMMODATING 95% OF U.S. ADULT MALE POPULATION


2.5%tile
50%tile
97.5%tile
5.7
64.4"
60.1
4.3
6.7
8.0
14.7
52.1
50.3
16.2
1.8
12.5
10.6
16.4
9.1
35.6
C.G.
33.9
6.4
15.7
22.9
18.2
3.6
15.2
2.7
3.0
2.3
0" datum
3.5
weight — 127.7 LB.
span — 65.5"
akimbo — 34.9"
6.1
69.1"
64.7
4.4
7.4
8.7
14.5
4.6
56.6
54.6
17.9
2.0
13.8
12.0
18.0
10.6
13.2
38.2
C.G.
36.6
32.8
2.5
6.9
95°
90°
54°
26.1
16.8
19.8
4.0
16.3
3.0
3.5
2.7
3.8
4.2 shoe
weight — 161.9 LB.
span — 70.8"
akimbo — 38.4"
6.5
76.5 total
74.0"
69.4
4.6
8.5
9.8
15.0
61.1
59.0
19.8
2.1
15.2
EQUAL
6.9
19.7
EQUAL
12.7
14.8
40.9
C.G.
45°
39.3
7.4
31
18.0
28.3
21.3
4.6
A.F. heavy winter clothing
17.5
dynamic link system shown
3.3
3.8
3.2
4.2
5.25
arctic shoe
weight — 208.9 LB.
span — 76.6"
akimbo — 42.4"

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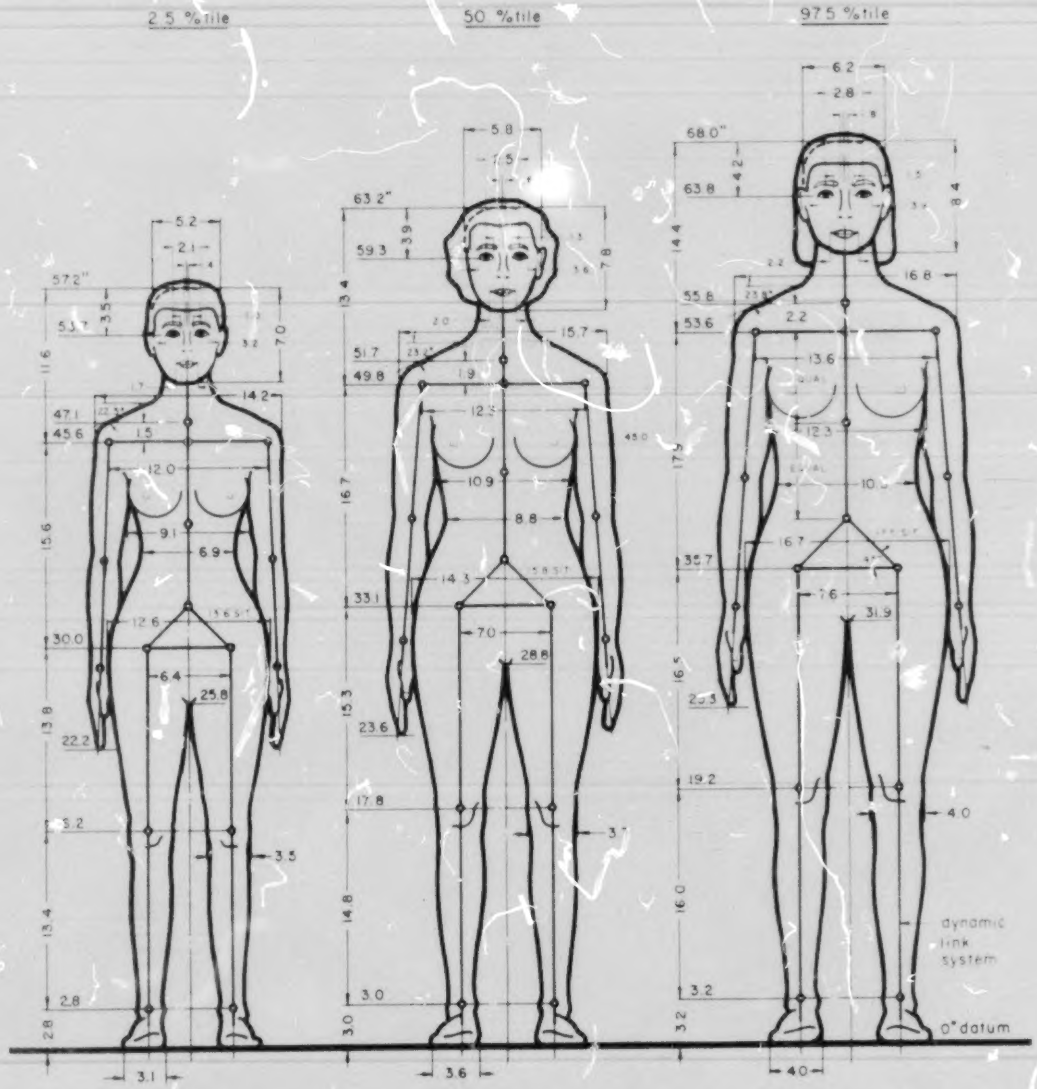
ASSIGNMENT SHEET #7

ANTHROPOMETRIC DATA – STANDING ADULT FEMALE

ACCOMMODATING 95% OF U.S. ADULT FEMALE POPULATION


2.5 %tile
50 %tile
97.5 %tile
5.2
2.1
57.2"
53.7
3.5
7.0
11.6
47.1
45.6
14.2
1.5
12.0
9.1
6.9
15.6
12.6
30.0
6.4
25.8
13.8
22.2
3.2
3.5
13.4
2.8
2.8
3.1
5.8
63.2"
59.3
3.9
7.8
13.4
51.7
49.8
15.7
1.9
12.3
10.9
8.8
16.7
14.3
33.1
7.0
28.8
15.3
23.6
17.8
14.8
3.0
3.0
3.6
6.2
2.8
68.0"
63.8
4.2
8.4
14.4
55.8
53.6
16.8
2.2
13.6
12.3
10.0
17.9
16.7
35.7
7.6
31.9
16.5
25.3
19.2
4.0
16.0
dynamic link system
3.2
3.2
0" datum
4.0

weight — 95.0 LB.
span — 58.8"
akimbo — 31.8"

weight — 134.8 LB.
span — 64.7"
akimbo — 34.7"

weight — 195.0 LB.
span — 70.2"
akimbo — 38.0"

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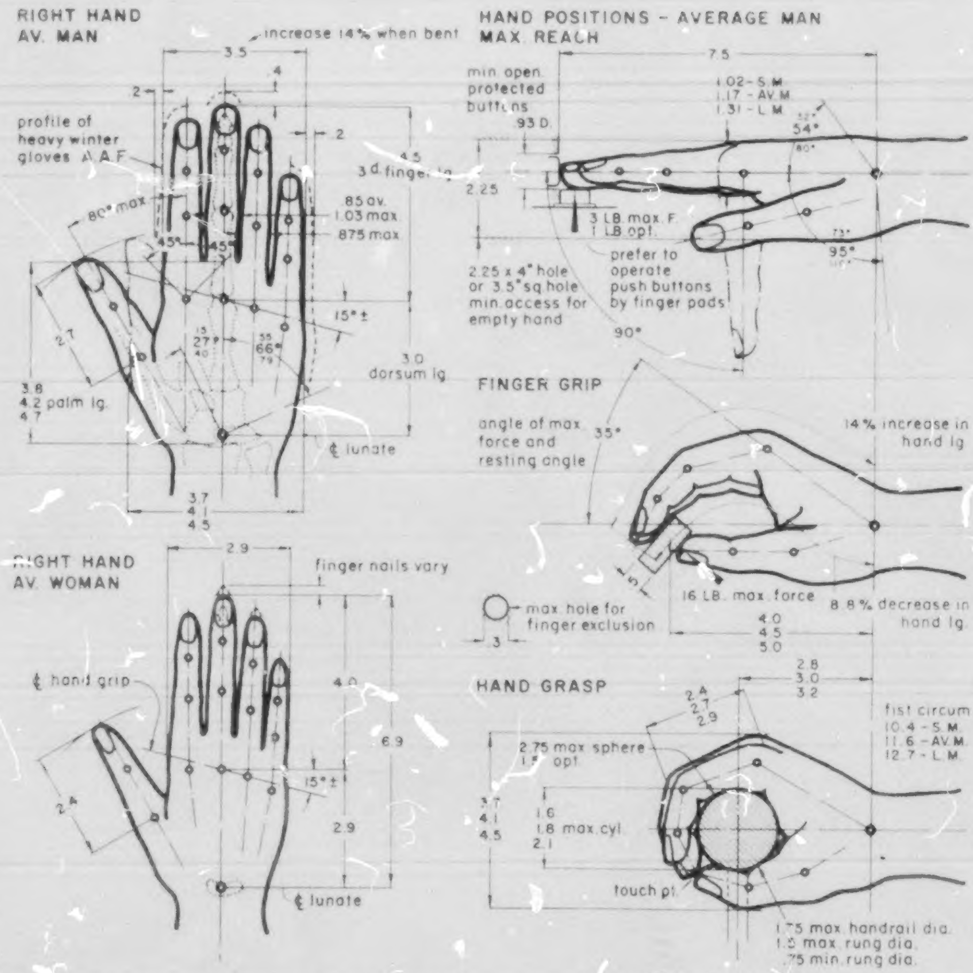
ASSIGNMENT SHEET #7

HAND MEASUREMENTS OF MEN, WOMEN AND CHILDREN


RIGHT HAND
AV. MAN
increase 14% when bent
3.5
.4
.2
.2
profile of heavy winter gloves A.A.F.
4.5
3d finger lg
.85 av.
1.03 max
.875 max
80° max
45°
45°
15°±
27°
66°
2.7
3.0
dorsum lg
3.8
4.2 palm lg.
4.7
℄ lunate
3.7
4.1
4.5
HAND POSITIONS - AVERAGE MAN
MAX. REACH
7.5
min. open protected buttons
.93 D.
1.02 - S.M.
1.17 - AV.M.
1.31 - L.M.
54°
2.25
3 LB. max. F.
1 LB. opt.
95°
2.25 x 4" hole or 3.5" sq. hole min. access for empty hand
prefer to operate push buttons by finger pads
90°
FINGER GRIP
angle of max. force and resting angle
35°
14% increase in hand lg.
.5
16 LB. max. force
8.8% decrease in hand lg.
max. hole for finger exclusion
.3
4.0
4.5
5.0
RIGHT HAND
AV. WOMAN
2.9
finger nails vary
℄ hand grip
4.0
6.9
15°±
2.4
2.9
℄ lunate
HAND GRASP
2.8
3.0
3.2
2.4
2.7
2.9
2.75 max. sphere
1.5 opt.
fist circum.
10.4 - S.M.
11.6 - AV.M.
12.7 - L.M.
3.7
4.1
4.5
1.6
1.8 max. cyl.
2.1
touch pt.
1.75 max. handrail dia.
1.5 max. rung dia.
.75 min. rung dia.

HAND DATA	MEN			WOMEN			CHILDREN			
	2.5 %tile	50. %tile	97.5 %tile	2.5 %tile	50. %tile	97.5 %tile	6 yr.	8 yr.	11 yr.	14 yr.
hand length	6.8	7.5	8.2	6.2	6.9	7.5	5.1	5.6	6.3	7.0
hand breadth	3.2	3.5	3.8	2.6	2.9	3.1	2.0	2.5	2.8	—
3d finger lg.	4.0	4.5	5.0	3.6	4.0	4.4	2.9	3.2	3.5	4.0
dorsum lg	2.8	3.0	3.2	2.6	2.9	3.1	2.2	2.4	2.8	3.0
thumb length	2.4	2.7	3.0	2.2	2.4	2.6	1.8	2.0	2.2	2.4

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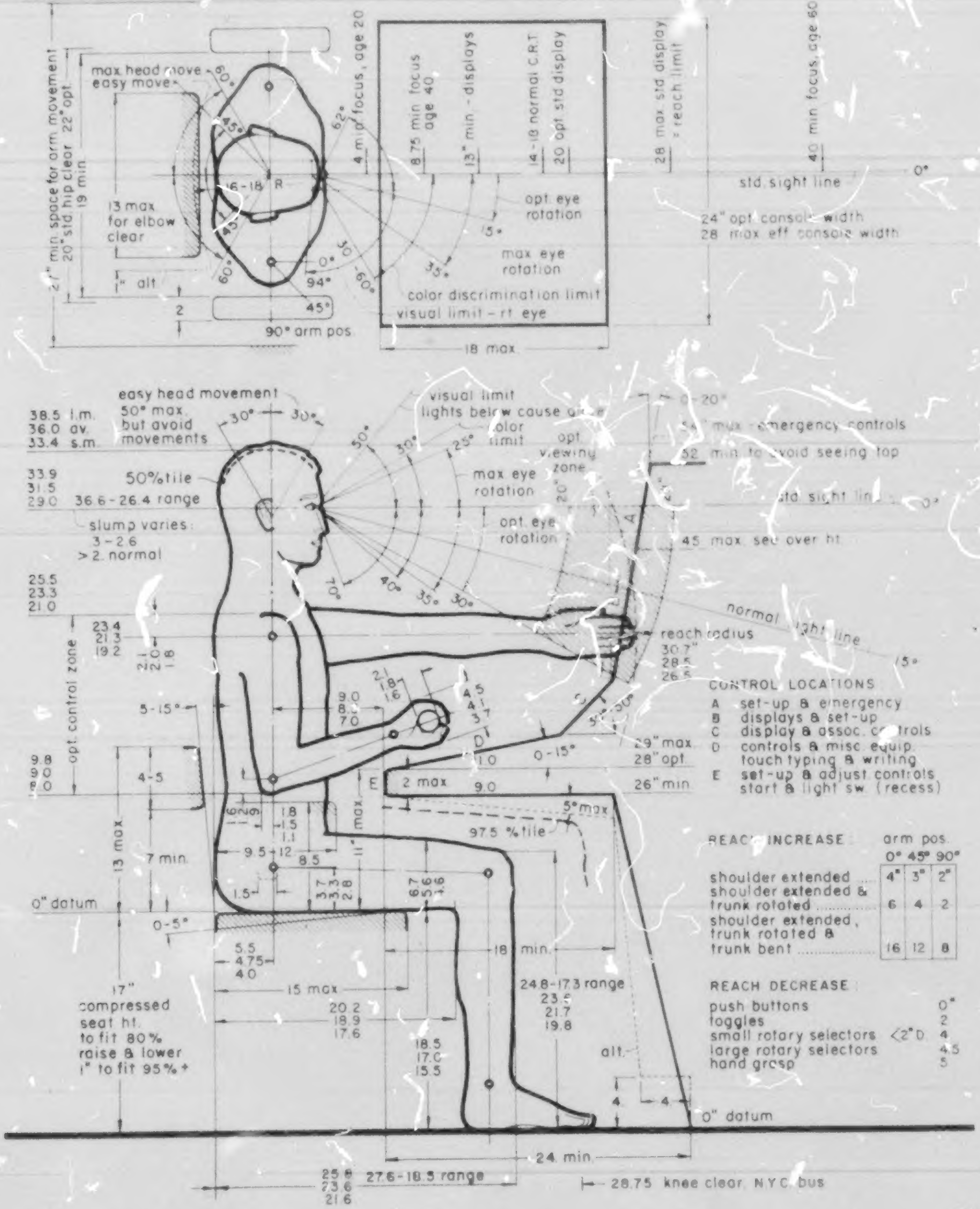
ASSIGNMENT SHEET #7

ANTHROPOMETRIC DATA — ADULT MALE SEATED AT CONSOLE


max head move 60°
easy move
21" min. space for arm movement
20" std. hip clear 22" opt.
19 min.
13 max for elbow clear
16-18
R
1" alt
2
90° arm pos.
45°
94°
60°
4 min focus, age 20
8.75 min focus age 40
13" min - displays
14-18 normal C.R.T.
20 opt std display
28 max. std display = reach limit
40 min focus, age 60
std. sight line
0°
opt eye rotation
15°
35°
max eye rotation
color discrimination limit
visual limit - rt eye
18 max
24" opt. console width
28 max eff console width
easy head movement 50° max. but avoid movements
38.5 l.m.
36.0 av.
33.4 s.m.
visual limit
lights below cause glare
color limit
opt. viewing zone
50%tile
33.9
31.5
29.0
36.6-26.4 range
slump varies 3-2.6 >2. normal
max eye rotation
opt. eye rotation
0-20°
54" max - emergency controls
52 min. to avoid seeing top
std. sight line 0°
45 max. see over ht.
normal sight line
15°
25.5
23.3
21.0
23.4
21.3
19.2
opt. control zone
reach radius 30.7" 28.5 26.5
5-15°
9.0
8.0
7.0
2.1
1.8
1.6
4.5
4.1
3.7
29" max.
28" opt.
26" min
0-15°
1.0
2 max
9.0
5° max
97.5 %tile
9.8
9.0
8.0
4-5
13 max
7 min.
0" datum
0-5°
9.5
12
8.5
1.5
1.8
1.5
1.1
3.7
3.3
2.8
6.7
5.6
4.6
11" max.
18 min.
5.5
4.75
4.0
15 max
20.2
18.9
17.6
24.8-17.3 range
23.5
21.7
19.8
18.5
17.0
15.5
alt.
4
4
0" datum
17" compressed seat ht. to fit 80% raise & lower 1" to fit 95%+
24 min.
25.8
23.6
21.6
27.6-18.5 range
28.75 knee clear N.Y.C. bus

CONTROL LOCATIONS

A set-up & emergency
B displays & set-up
C display & assoc. controls
D controls & misc. equip. touch typing & writing
E set-up & adjust. controls start & light sw. (recess)

REACH INCREASE	arm pos 0°	45°	90°
shoulder extended	4"	3"	2"
shoulder extended & trunk rotated	6	4	2
shoulder extended, trunk rotated & trunk bent	16	12	8

REACH DECREASE		
push buttons		0"
toggles		2
small rotary selectors	<2" D.	4
large rotary selectors		4.5
hand grasp		5

6.6-9.% left handed, 3.5-6.% color blind, 4.5% hard of hearing, 29.3% wear glasses

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DIMENSIONING AND TOLERANCING
UNIT V

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1--Evaluated to the satisfaction of the instructor

Assignment Sheet #2

A. $\frac{.9992}{.9984}$ $\frac{2.4996}{2.4991}$

$\frac{1.0008}{1.0000}$ $\frac{2.5007}{2.5000}$

B. $\frac{39.991}{39.975}$ $\frac{2.500}{2.475}$

Assignment Sheet #3

A. $\frac{3.0047}{3.0040}$ $\frac{.5011}{.5007}$

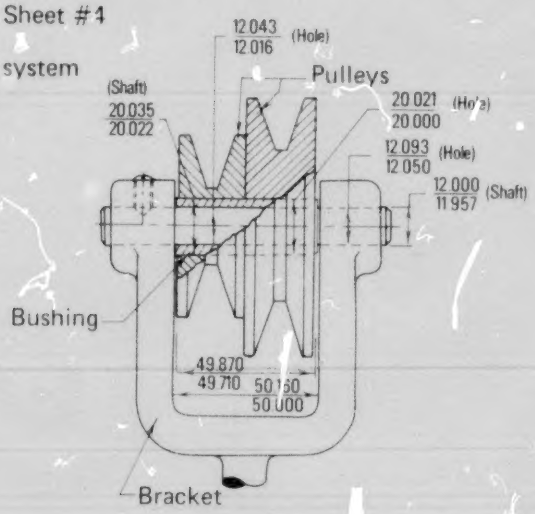
$\frac{3.0012}{3.0000}$ $\frac{.5007}{.5000}$

B. $\frac{10.000}{9.991}$ $\frac{1.200}{1.194}$

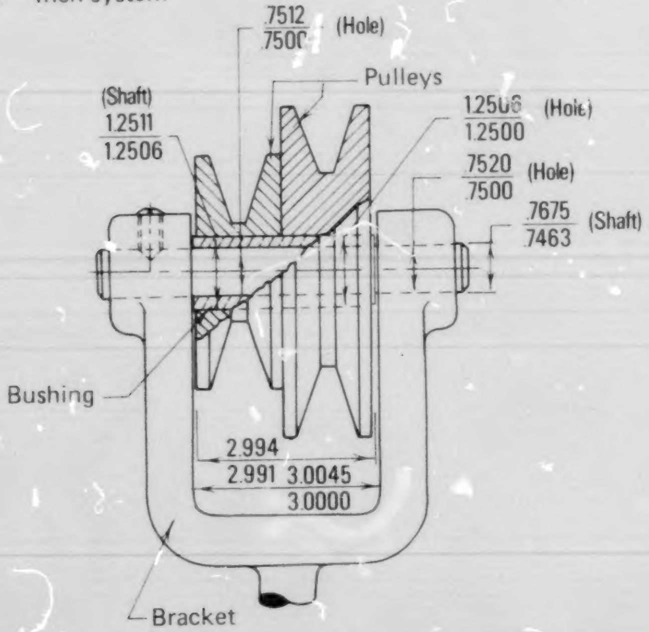
$\frac{9.978}{9.963}$ $\frac{1.194}{1.184}$

Assignment Sheet #4

A. Metric system


12.043
12.016
(Hole)
Pulleys
(Shaft)
20.035
20.022
20.021
20.000
(Hole)
12.093
12.050
(Hole)
12.000
11.957
(Shaft)
Bushing
49.870
49.710
50.160
50.000
Bracket

B. Inch system


.7512
.7500 (Hole)
Pulleys
(Shaft)
1.2511
1.2506
1.2506 (Hole)
1.2500
.7520 (Hole)
.7500
.7675 (Shaft)
.7463
Bushing
2.994
2.991
3.0045
3.0000
Bracket

Assignment Sheet #5

A. Clearance $\frac{.7512}{.7505}$ B. Interference $\frac{.7494}{.7483}$

Assignment Sheet #6--Evaluated to the satisfaction of the instructor

Assignment Sheet #7

A. 19.8"
B. 69.1"
C. 120°
D. 4.5"
E. 2.8"
F. 2.4"

DIMENSIONING AND TOLERANCING
UNIT V

NAME______________________________

TEST

1. Match the terms on the right with the correct definitions.

______a. The condition that refers to a part made to limit dimensions so that it will fit any part similarly manufactured; the ability of mating parts to fit properly together

______b. Shapes such as prisms, cylinders, pyramids, cones, and spheres

______c. Any type of dimension that tells how large or small an object is

______d. Any type of dimension that locates a feature on an object

______e. The total amount of variation permitted in limit dimensioning of a part; the difference between the limit dimensions

______f. The size of a part determined by engineering and design requirements from which the limits of size are determined; the line of zero deviation

______g. The extreme permissible dimensions of a part resulting from the application of a tolerance; the maximum and minimum size indicated by a tolerance

______h. Used when maximum material is present in a feature

______i. Used when the least material is present in a feature

______j. Difference between the maximum limit and the basic size

______k. Difference between the minimum limit and the basic size

______l. Group of tolerances numbered 01 - 16

______m. The deviation nearer the basic size for the hole and near the basic size for the shaft

1. Limits
2. Interference fit
3. Waviness
4. Lower deviation
5. Basic shaft system
6. Positional tolerance
7. Lay
8. Interchangeability
9. Transition fit
10. Maximum material condition
11. Basic size
12. Fundamental deviation
13. Size dimension
14. Upper deviation

______n. The association of a fundamental deviation with an international tolerance grade

______o. The basic size of the hole is the design size and the allowance is applied to the shaft

______p. The basic size of the shaft is the design size and the allowance is applied to the hole

______q. Limits of size are determined so that a loose fit or positive allowance occurs between mating parts

______r. Limits of size are determined so that a negative allowance or tight fit occurs between mating parts

______s. Limits of size are determined so that the allowance may be either a clearance fit or an interference fit

______t. The minimum international difference in the dimensions of mating parts to provide for different classes of fits; the minimum clearance or maximum interference when parts are at maximum material condition

______u. Points, lines, or other geometric shapes assumed to be exact from which the location or geometric form of features of a part may be established

______v. Exact theoretical position of a feature established by basic dimensions

______w. Maximum allowable variations of a perfect geometric shape

______x. Roughness, waviness, and lay of a surface which may include certain flaws

______y. Direction of the major surface pattern determined by manufacturing method used

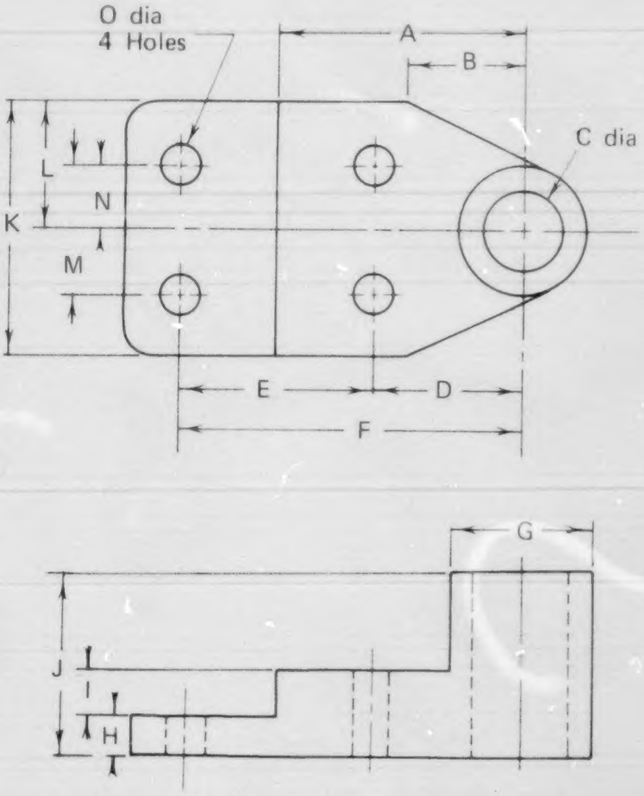
______z. Fine irregularities in surface texture

______aa. Widely spaced element of a surface texture

______bb. Measurements of the human body and its parts

15. Clearance fit
16. Basic hole system
17. Roughness
18. Allowance
19. Anthropometric data
20. Tolerance
21. Surface quality
22. Location dimension
23. Datums
24. Least material condition
25. International tolerance grade
26. Form tolerances
27. Geometric shapes
28. Tolerance zone

2. Distinguish between size and location dimensions for the following geometric shape by placing an "X" next to the size dimensions.



______a. Dimension "A"

______b. Dimension "B"

______c. Dimension "C"

______d. Dimension "D"

______e. Dimension "E"

______f. Dimension "F"

______g. Dimension "G"

______h. Dimension "H"

______i. Dimension "I"

______j. Dimension "J"

______k. Dimension "K"

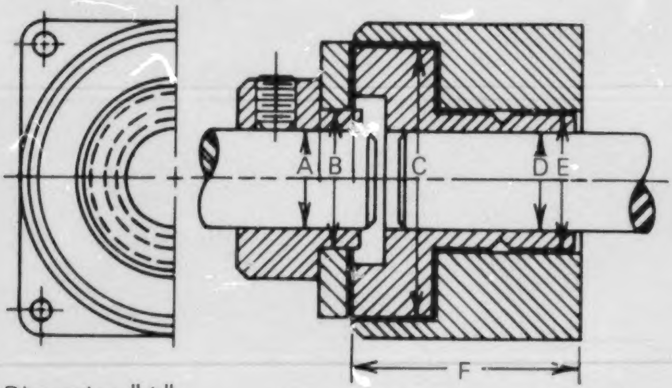
______l. Dimension "L"

______m. Dimension "M"

______n. Dimension "N"

______o. Dimension "O"

3. Select mating dimensions in the following assembly drawing by placing an "X" in the appropriate blanks.



______a. Dimension "A"

______b. Dimension "B"

______c. Dimension "C"

______d. Dimension "D"

______e. Dimension "E"

______f. Dimension "F"

4. Select true statements concerning numerical control dimensioning by placing an "X" in the appropriate blanks.

______a. Datum or reference planes must be selected that are mutually perpendicular in the X, Y, and Z axes

______b. Dimensions originate from two planes

______c. Dimensions must be in fractions

______d. Standard tools such as reamers, drills, and tapers should be specified wherever possible

5. Distinguish between fits for inch units and fits for metric units by placing an "X" next to the fits for inch units and an "O" next to the fits for metric units.

______a. RC 2

______b. H9/d9

______c. H7/h6

______d. FN 3

______e. LT 1

______f. N7/h6

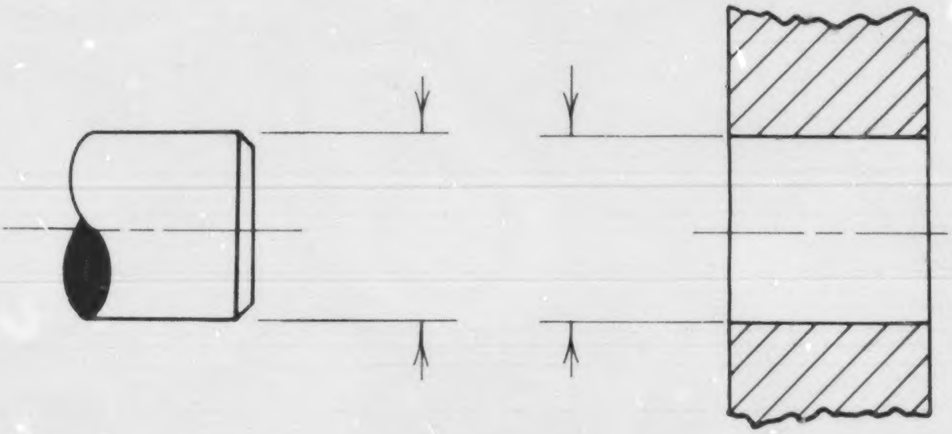
______g. P7/h6

______h. U7/h6

______i. LC 1

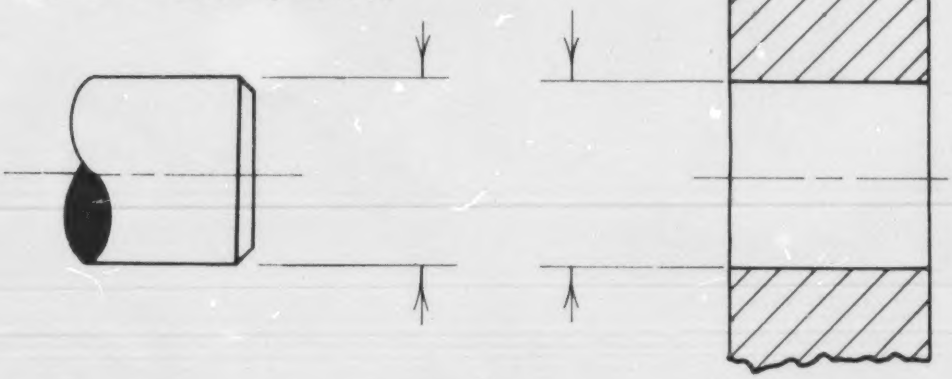
6. Calculate the limits for clearance fit in inch units using basic hole system for basic hole size of 2.25" and RC 4 fit. Place answers on drawing.

	RC 3			RC 4			
NOMINAL SIZE RANGE, INCHES	LIMITS OF CLEARANCE	STANDARD LIMITS HOLE	STANDARD LIMITS SHAFT	LIMITS OF CLEARANCE	STANDARD HOLE	LIMITS SHAFT	
1.19 - 1.97	- 1.0 - 2.6	+ 1.0 - 0	- 1.0 - 1.6	1.0 3.6	+ 1.6 - 0	- 1.0 - 2.0	
1.97 - 3.15	1.2 3.1	+ 1.2 - 0	- 1.2 - 1.9	1.2 4.2	+ 1.8 - 0	- 1.2 - 2.4	



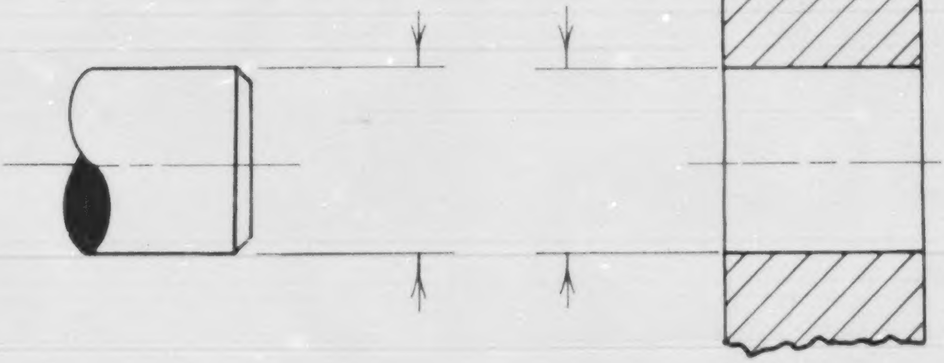
7. Calculate the limits for clearance fit in inch units using basic shaft system for basic shaft size of 1.75 and RC 3 fit. Place answers on drawing.

(NOTE: Use table in question 6.)



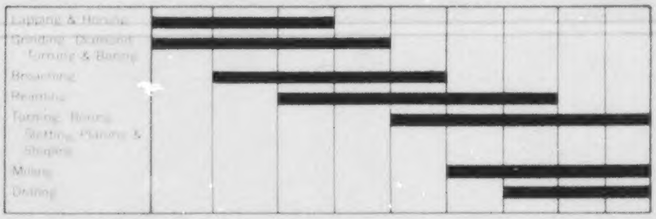
8. Calculate the limits for an interference fit in metric units using basic hole system for basic hole size of 60 mm and H7/u6 fit. Place answers on drawing.

BASIC SIZE	HOLE H7	SHAFT u6	FIT
60	60.030 60.000	60.106 60.087	-0.057 -0.106
80	80.030 80.000	80.121 80.102	-0.072 -0.121



9. Determine the tolerance ranges for the following shop processes using the accompanying table.

Range of Sizes From	To & Incl.	Tolerances								
.000	.599	.00015	.0002	.0003	.0005	.0008	.0012	.002	.003	.005
.600	.999	.00015	.00025	.0004	.0006	.001	.0015	.0025	.004	.006
1.000	1.499	.0002	.0003	.0005	.0008	.0012	.002	.003	.005	.008
1.500	2.799	.00025	.0004	.0006	.001	.0015	.0025	.004	.006	.010
2.800	4.499	.0003	.0005	.0008	.0012	.002	.003	.005	.008	.012
4.500	7.799	.0004	.0006	.001	.0015	.0025	.004	.006	.010	.015
7.800	13.599	.0005	.0008	.0012	.002	.003	.005	.008	.012	.020
13.600	20.999	.0006	.001	.0015	.0025	.004	.006	.010	.015	.025



a. Milling of a 1.5 to 2.799 part ______________________________

b. Reaming of a .6 to .999 part ______________________________

c. Drilling of a 4.5 to 7.799 part ______________________________

d. Honing of a .000 to .599 part ______________________________

10. Distinguish between clearance fit and interference fit of hole size limits for standard dowels by placing an "X" next to the characteristic of clearance fit.

    ______a. Largest number is tightest fit and is negative; smallest number is loosest fit and is negative

    ______b. Smallest number is tightest fit; largest number is loosest fit

11. Select true statements concerning limit dimensions for interchangeability of parts by placing an "X" in the appropriate blanks.

    ______a. Parts should be toleranced to fit end-for-end to make assembly easier if function is not affected

    ______b. Select the center dimension to be basic size

    ______c. Maximum accumulation should be added to center

    ______d. When each part is toleranced, it is not necessary to check the accumulation of tolerance

12. Arrange in order the steps for determining limit dimensions for intermediate parts to retain overall limits by placing the correct sequence numbers in the appropriate blanks.

    ______a. Divide total tolerance accumulation by number of toleranced parts to get tolerance per part

    ______b. Subtract upper and lower limits of overall dimension to get total tolerance accumulation

    ______c. Add tolerance per part to each basic size to get upper limit of each part

    ______d. Find limit dimensions

    ______e. Check by adding upper limits together to get upper limit of overall dimension

13. Complete the following chart of characteristic symbols for tolerances of position and form.

		Characteristic Symbols	
Form Tolerances	Individual Features	Straightness	—
		Flatness	
			○
		Cylindricity	⌭
	Individual or Related Features	Profile of a line	⌒
		Profile of a surface	⌓
	Related Features	Angularity	∠
		Perpendicularity	
			//
Location Tolerances		Position	⌖
		Concentricity	◎
		Symmetry	
Runout Tols.		Circular	↗
		Total	↗

14. Match the terms on the right with the correct supplementary symbols for tolerances of position and form.

_____a. Ⓢ

_____b. Ⓜ

_____c. ▭

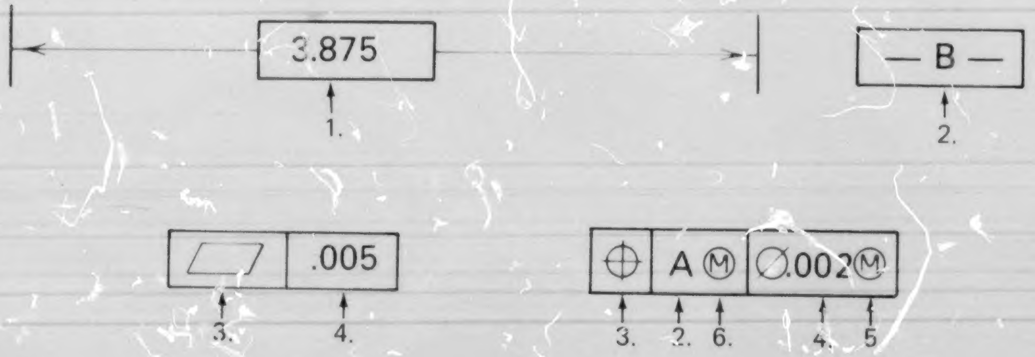
_____d. (   )

_____e. ∅

_____f. Ⓟ

1. Basic
2. Diameter
3. Maximum material condition
4. Projected tolerance zone
5. Regardless of feature size
6. Reference

15. Match position and form symbols in the drawing with the correct descriptions below.


3.875
1.
— B —
2.
.005
3.
4.
A Ⓜ
∅.002Ⓜ
3.
2.
6.
4.
5

______a. Geometric characteristic symbol

______b. Modifier of datum

______c. Datum reference

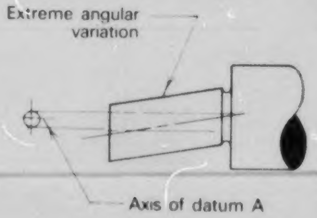
______d. Basic dimension symbol

______e. Tolerance

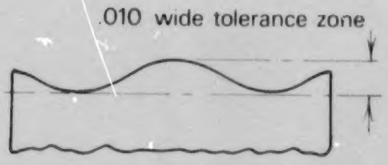
______f. Modifier of tolerance

16. Match the descriptions of position and form on the right with the correct meaning of drawings.

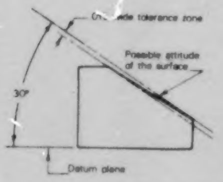
______a.


Extreme angular variation
Axis of datum A

______b.

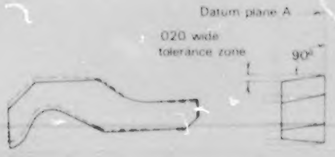

.010 wide tolerance zone

______c.

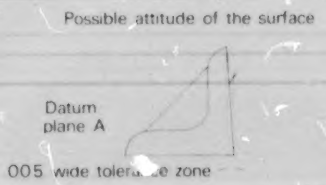

wide tolerance zone
Possible attitude of the surface
30°
Datum plane

1. Flatness
2. Angularity
3. Concentricity
4. Profile of a surface
5. Perpendicularity

______d.



______e.



17. Select true statements concerning positional tolerancing by placing an "X" in the appropriate blanks.

______a. Conventional limit locational dimensions have a square tolerance zone

______b. Positional tolerancing allows a circular tolerance zone

______c. Positional tolerancing allows more tolerance than conventional limit dimensions

______d. Extreme angular variation in drilling a hole under positional tolerancing is not possible

______e. No tolerance accumulation is found in positional tolerancing

18. Distinguish between maximum material condition and regardless of feature size by placing an "X" next to the characteristic of maximum material condition.

______a. More restrictive

______b. Less restrictive

19. Select true statements concerning angular tolerances by placing an "X" in the appropriate blanks.

______a. Bilateral angular tolerances cause a smaller tolerance zone as you move from the vertex

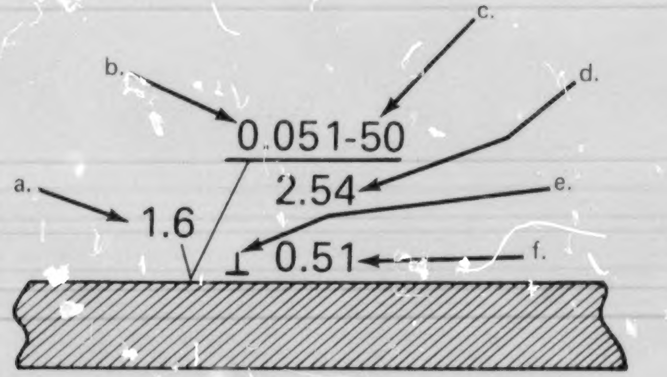
______b. Basic angular tolerances using angular feature controls cause a parallel tolerance zone

20. State the purpose of surface quality specifications.

____

____

21. Identify parts of a surface quality symbol.



a. ______________________ b. ______________________

c. ______________________ d. ______________________

e. ______________________ f. ______________________

22. Select true statements concerning surface quality notes by placing an "X" in the appropriate blanks.

_____a. Values are in decimeters

_____b. Lower number of values indicate rougher surface

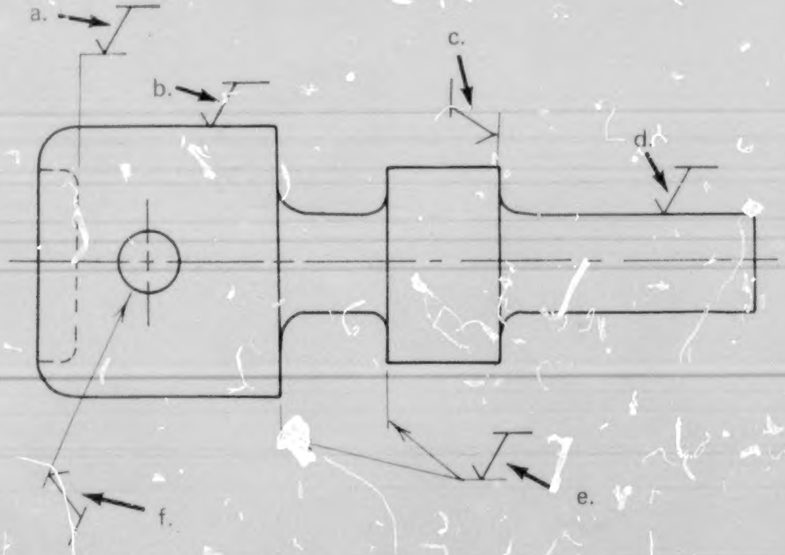
_____c. Symbol is always made in the standard upright position

_____d. The smoothest surface that will satisfy function and form is the ideal finish

23. Match lay symbols on the right with the correct designation.

_____a. Angular to surface	1. =
_____b. Radial	2. ⊥
_____c. Particulate, nondirectional, or protuberant	3. X
_____d. Parallel to surface	4. M
_____e. Multidirectional	5. C
_____f. Perpendicular to surface	6. R
_____g. Circular	7. P^3

24. Differentiate between correct and incorrect placement of surface quality symbols by placing an "X" in the blanks which correspond to symbols placed correctly.



_____a.

_____b.

_____c.

_____d.

_____e.

_____f.

25. Select true statements concerning surface roughness produced by common production methods by placing an "X" in the appropriate blanks by using the accompanying table.

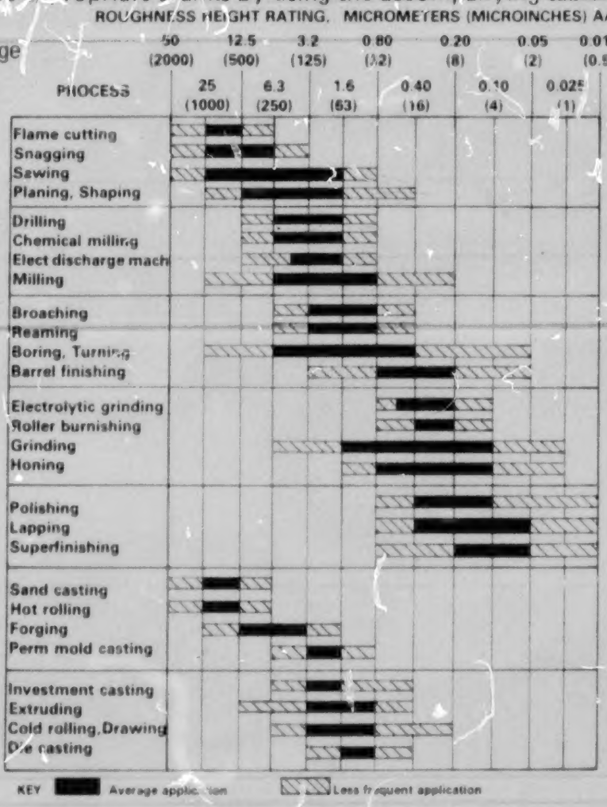
_____a. Drilling process average 6.3 thru 1.6 micrometers

_____b. Reaming process less frequent range 6.3 thru .40 micrometers

_____c. Grinding process average 1.6 thru .025 micrometers

_____d. Forging process average 12.5 thru 3.2 micrometers

_____e. Die casting process average 50 thru .20 micrometers



26. Select *preferred* recommended roughness, waviness, and roughness width cutoff values from table by placing an "X" in the appropriate blanks.

Recommended Roughness
Average Rating Values
Micrometers (Microinches)

μm	μin.	μm	μin.
0.025	(1)	1.25	(50)
0.050	**(2)**	**1.6**	**(63)**
0.075	(3)	2.0	(80)
0.100	**(4)**	2.5	(100)
0.125	(5)	**3.2**	**(125)**
0.15	(6)	4.0	(160)
0.20	**(8)**	5.0	(200)
0.25	(10)	**6.3**	**(250)**
0.32	(13)	8.0	(320)
0.40	**(16)**	10.0	(400)
0.50	(20)	**12.5**	**(500)**
0.63	(25)	15.0	(600)
0.80	**(32)**	20.0	(800)
1.00	(40)	25.0	(1000)

Recommended Waviness
Height Values,
Millimeters (Inches)

mm	in.	mm	in.
0.0005	**(.00002)**	**0.025**	**(.0010)**
0.008	(.00003)	**0.05**	**(.002)**
0.0012	**(.00005)**	0.08	(.003)
0.0020	(.0008)	**0.12**	**(.005)**
0.0025	**(.00010)**	0.20	(.008)
0.005	**(.0002)**	**0.25**	**(.010)**
0.008	(.0003)	0.38	(.015)
0.012	**(.0005)**	**0.50**	**(.020)**
0.020	(.0008)	0.80	(.030)

Recommended
Standard Roughness
Width Cutoff Values
Millimeters (Inches)

mm	in.	mm	in.
0.08	(0.03)	2.50	(.100)
0.25	(.013)	8.0	(.300)
0.80	**(.030)**	25.0	(1.000)

______a. .075 μm Roughness

______b. .20 mm Waviness height

______c. .80 mm Roughness width cutoff

27. Demonstrate the ability to:

    a. Dimension an object completely.

    b. Calculate and dimension clearance fit tolerances using standard fit tables.

    c. Calculate and dimension interference fit tolerances using standard fit tables.

    d. Calculate and assign tolerances to mating parts using standard fit tables.

    e. Calculate and dimension hole size limits for standard dowels.

    f. Dimension an object using position and form tolerances.

    g. Determine ranges of motion of limbs and spaces required for a person.

    (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

DIMENSIONING AND TOLERANCING
UNIT V

ANSWERS TO TEST

1. a. 8
   b. 27
   c. 13
   d. 22
   e. 20
   f. 11
   g. 1
   h. 10
   i. 24
   j. 14
   k. 4
   l. 25
   m. 12
   n. 28
   o. 16
   p. 5
   q. 15
   r. 2
   s. 9
   t. 18
   u. 23
   v. 6
   w. 26
   x. 21
   y. 7
   z. 17
   aa. 3
   bb. 19

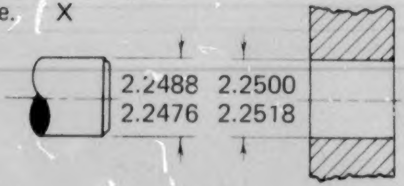
2. a, b, c, f, g, h, i, j, k, o

3. a, b, c, d, e

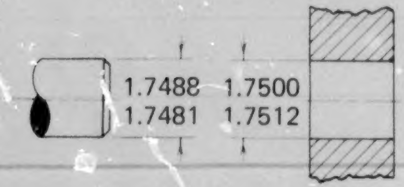
4. a, d

5. a. X
   b. O
   c. O
   d. X
   e. X
   f. O
   g. O
   h. O
   i. X

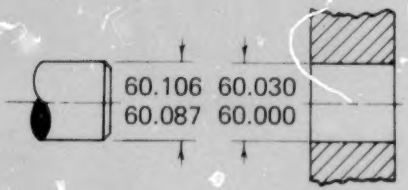
6.


2.2488
2.2476
2.2500
2.2518

7.


1.7488
1.7481
1.7500
1.7512

8.


60.106
60.087
60.030
60.000

9. a. .0025 - .010
   b. .0004 - .0025
   c. .006 - .015
   d. .00015 - .0003

10. b

11. a, b

12. a. 3
    b. 2
    c. 4
    d. 1
    e. 5

13.

		Characteristic Symbols	
Form Tolerances	Individual Features	Straightness	⏤
		Flatness	▱
		Roundness; Circularity	○
		Cylindricity	⌭
	Individual or Related Features	Profile of a line	⌒
		Profile of a surface	⌓
	Related Features	Angularity	∠
		Perpendicularity	⊥
		Parallelism	//
Location Tolerances		Position	⌖
		Concentricity	◎
		Symmetry	⌯
Runout Tols.		Circular	↗
		Total	↗

14. a. 5
    b. 3
    c. 1
    d. 6
    e. 2
    f. 4

15. a. 3
    b. 6
    c. 2
    d. 1
    e. 4
    f. 5

16. a. 3
    b. 1
    c. 2
    d. 4
    e. 5

17. a, b, c, e

18. b

19. b

20. Used where heavy loads and high speeds with less friction are needed

21. a. Roughness height
    b. Waviness height
    c. Waviness width
    d. Roughness width cutoff
    e. Roughness width
    f. Lay

22. c

23. a. 3
    b. 6
    c. 7
    d. 1
    e. 4
    f. 2
    g. 5

24. a, b, d, e

25. a, b, d

26. c

27. Evaluated to the satisfaction of the instructor

FASTENERS AND HARDWARE
UNIT VI

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify fasteners and symbols and construct symbols and hardware drawings. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to fasteners and hardware with the correct definitions.
2. Name two general types of fasteners.
3. Name three basic applications of screw threads.
4. Identify screw thread nomenclature.
5. Identify screw thread profiles.
6. Compute lead of thread.
7. Identify screw thread symbols.
8. Match classes of fit for unified threads with the correct uses.
9. List two classes of fit for metric threads.
10. Identify parts of thread notes.
11. Distinguish between conventional representations of pipe threads.
12. List types of threaded removable fasteners.
13. Name two shapes of bolts and nuts.
14. Select types of locknuts and locking devices.
15. Name types of standard cap screws.
16. Complete a list of types of machine screws.
17. Identify set screw heads and points.
18. Identify miscellaneous bolts and screws.

19. Identify standard large and small rivets.

20. Match conventional rivet symbols with the correct identifications.

21. List advantages of plastic fasteners over metal fasteners.

22. Select devices to lock components on a shaft.

23. List types of springs.

24. Identify types of springs according to notes and dimensions.

25. Name types of spring clips.

26. Select types of keys to prevent relative motion between wheel and shaft.

27. Identify types of machine pins.

28. Select true statements concerning washers.

29. List two applications of inserts.

30. Distinguish between types of lock washers.

31. Name uses for spring washer designs.

32. Identify quick opening and locking devices.

33. Match miscellaneous machine elements with the correct uses.

34. Name advantages of welding over threaded fasteners.

35. Identify types of welded joints.

36. Label parts of a welding symbol.

37. Identify basic arc and gas weld symbols.

38. Identify supplementary welding symbols.

39. Determine welding dimensions for a fillet weld.

40. Identify resistance welding symbols.

41. Name classifications of methods of using adhesives for bonding materials.

42. List two joint design considerations for adhesive bonding.

43. Select joint designs for adhesive bonding.

44. Demonstrate the ability to:
    a. Construct thread symbols.
    b. Construct bolts, screws, and nuts.

c. Construct an assembly containing various fasteners.

d. Construct a welded assembly drawing.

e. Construct spring drawings to include specifications.

f. Construct keys in assembled positions.

g. Write specifications for hardware from vender catalogs.

FASTENERS AND HARDWARE
UNIT VI

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and assignment sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Have students tour a hardware store searching out various fasteners. A display of various fasteners in the classroom would improve learning of this unit.

VII. Have students tour a welding lab to see how parts are welded together.

VIII. Assemble a display of various hardware items obtainable from a hardware store and discuss their possible uses.

IX. Have various springs for the students to see.

X. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet

  B. Information sheet

  C. Transparency masters

    1. TM 1--Screw Thread Nomenclature
    2. TM 2--Screw Thread Profiles
    3. TM 3--Screw Thread Symbols
    4. TM 4--Combined Screw Thread Symbols
    5. TM 5--American National Thread Note for Holes
    6. TM 6--American National Thread Notes for Threaded Shaft
    7. TM 7--American Standard Unified Thread Notes
    8. TM 8--Metric Thread Notes

9. TM 9--Pipe Threads
10. TM 10--Removable Fasteners
11. TM 11--Locknuts and Locking Devices
12. TM 12--Standard Cap Screws
13. TM 13--Machine Screws
14. TM 14--Set Screws
15. TM 15--Miscellaneous Bolts and Screws
16. TM 16--Miscellaneous Bolts and Screws (Continued)
17. TM 17--Standard Large Rivets
18. TM 18--Small Rivets
19. TM 19--Rivet Symbols
20. TM 20--Design with Rivets
21. TM 21--Shaft Locking Hardware
22. TM 22--Springs
23. TM 23--Schematic Spring Drawing Representative
24. TM 24--Clips
25. TM 25--Keys
26. TM 26--Pins
27. TM 27--Washers
28. TM 28--Tooth Lock Washers
29. TM 29--Quick Locking Devices
30. TM 30--Attaching Resistance Weld Fasteners
31. TM 31--Welding Advantages
32. TM 32--Types of Welded Joints
33. TM 33--Parts of a Welding Symbol
34. TM 34--Basic Arc and Gas Welding Symbol
35. TM 35--Supplementary Symbols
36. TM 36--Dimensioning of Welds

37. TM 37--Resistance Welding Symbols
38. TM 38--Stresses on Bonded Joints
39. TM 39--Joint Design for Adhesive Bonding

D. Assignment sheets

1. Assignment Sheet #1--Construct Thread Symbols
2. Assignment Sheet #2--Construct Bolts, Screws, and Nuts
3. Assignment Sheet #3--Construct an Assembly Containing Various Fasteners
4. Assignment Sheet #4--Construct a Welded Assembly Drawing
5. Assignment Sheet #5--Construct Spring Drawings to Include Specifications
6. Assignment Sheet #6--Construct Keys in Assembled Positions
7. Assignment Sheet #7--Write Specifications for Hardware from Vender Catalogs

E. Test

F. Answers to test

II. References:

A. Jensen, Cecil, and Jay Helsel. *Engineering Drawing and Design.* St. Louis, MO 63100: Gregg Division/McGraw-Hill Book Co., 1979.

B. Parmley, Robert O. *Standard Handbook of Fastening and Joining.* New York: McGraw-Hill Book Co., 1977.

C. Giesecke, Frederick E., et al. *Technical Drawing.* 7th ed. New York 10022: Macmillan Publishing Co., Inc., 1980.

D. Levens, Alexander, and William Chalk. *Graphics in Engineering Design.* 3rd ed. New York: John Wiley and Sons, 1980.

E. American National Standards Institute, 1430 Broadway, New York, NY 10018.

F. *1980 Fastening and Joining Reference Issue, Machine Design.* Vol. 52, #26. Penton/IPC Inc., November 13, 1980.

G. Beakley, George C. and Ernest G. Chilton. *Design Serving the Needs of Man.* New York: Macmillan Publishing Co., 1974.

H. *Fasteners Standards,* 5th edition. Cleveland, OH 44114: Industrial Fasteners Institute, 1970.

FASTENERS AND HARDWARE
UNIT VI

INFORMATION SHEET

I. Terms and definitions

  A. Fastener--Mechanical device for holding two or more parts in a set position

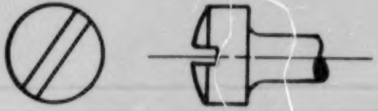
  B. Finished fastener--Fastener made to close tolerance having a high grade finish

  C. High strength fastener--Fastener having high tensile and shear strength

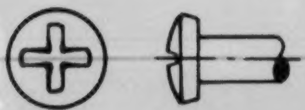
  D. Semi-finished fastener--Fastener made with greater tolerances than a finished fastener and having only the bearing surface and threads finished

  E. Unfinished fastener--Fastener with wide tolerances and all surfaces in their formed conditions

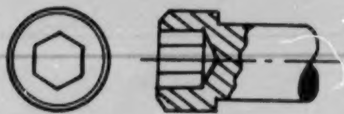
  F. Slotted head--Head having a slot centered across the top



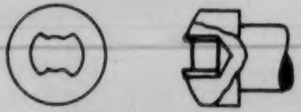
  G. Recessed head--Head having a specially formed indentation centered in its top



Cross (Phillips)



Socket



Clutch

  H. Screw thread form--Profile of the thread

  I. Detailed threads--Close approximation to actual appearance

  J. Schematic threads--More detailed than simplified but faster to draw than detailed threads

  K. Simplified threads--Least amount of drawing information necessary to convey information without confusion

  L. External thread--Thread on the outside of a shaft

  M. Internal thread--Thread on the inside of a hole

  N. Lead--Distance a screw travels in one rotation

INFORMATION SHEET

O. Series of thread--Number of threads per inch based on standard nominal diameters

P. Single thread--Thread having one start, and the lead is equal to the pitch

Q. Multiple threads--Thread having multiple starts, and the lead is equal to a multiple of the pitch

Example: Double thread has a lead of twice the pitch

R. Right-hand thread--Advances when turned clockwise

S. Left-hand thread--Advances when turned counterclockwise

T. Welding--Joining parts by melting base metal to form a unit structure to support loads

U. Adhesive--Chemical bonding between parts

V. Hardware--Small parts such as fasteners, springs, and washers

W. Springs--Used for storage of mechanical energy

X. Keys--Used to attach wheels, pulleys, and gears to shafts

Y. Washers--Designed to insulate, lubricate, span large holes, and distribute stress over a larger area

Z. Nuts--Designed for fastening, adjusting, and transmitting motion or power

AA. Pins--Designed for semi-permanent attachment or location

BB. O-Rings--Used to seal along a shaft

CC. Retaining ring--Has a removable shoulder to accurately retain, locate, or lock components in bases and housings or on shafts

(NOTE: This is also called a snap ring.)

II. General types of fasteners

A. Removable

Example: Bolts, keys, screws

B. Permanent

Example: Rivets, welds, adhesives

INFORMATION SHEET

III. Basic applications of screw threads

   A. Holding parts together

   B. Adjustment

   C. Power transmission

IV. Screw thread nomenclature (Transparency 1)

   A. Crest

   B. Root

   C. Side

   D. Major diameter

   E. Pitch diameter

   F. Minor diameter

   G. Depth

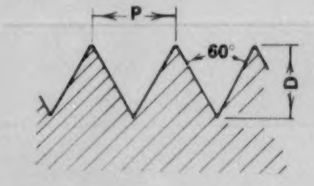
   H. Axis

   I. Thread angle

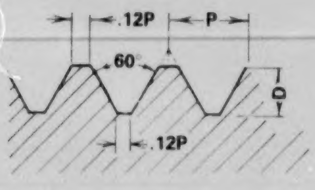
   J. Pitch

V. Screw thread profiles (Transparency 2)

   A. Sharp V--Adjustments

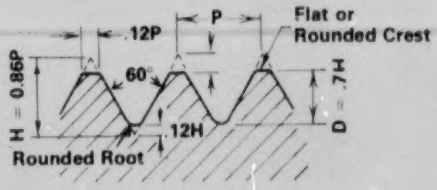


   B. American National--General purpose

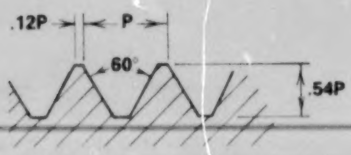


INFORMATION SHEET

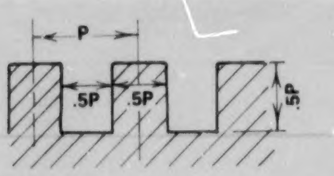
C. Unified


.12P
P
Flat or Rounded Crest
H = 0.86P
60°
D = .7H
.12H
Rounded Root

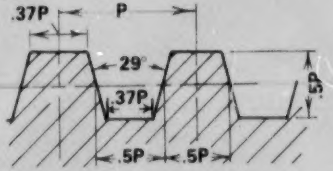
D. Metric



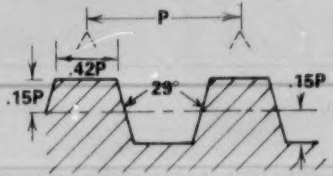
E. Square



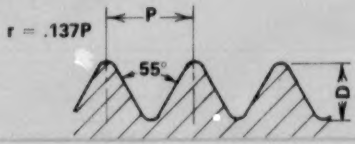
F. Acme--General purpose


.37P
P
29°
.37P
.5P
.5P
.5P

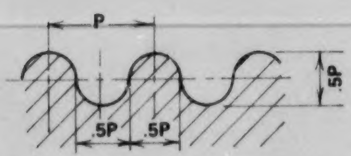
G. Acme--Stub


P
.42P
.15P
29°
.15P

H. Whitworth Standard

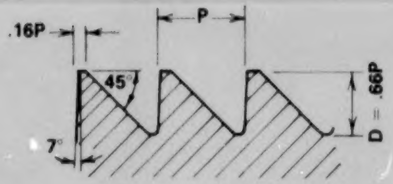


I. Knuckle



INFORMATION SHEET

J. Buttress



VI. Computing lead of thread

A. Single thread lead = Pitch

B. Double thread lead = (2)(Pitch)

C. Triple thread lead = (3)(Pitch)

D. Multi-threads lead = (Number of threads)(Pitch)

(NOTE: Pitch = $\frac{1}{\text{Number of threads per inch}}$)

Example: 12 threads per inch

$\text{Pitch} = \frac{1}{12}$

$\text{Lead} = \frac{1}{12}$ for single thread

$\text{Lead} = \frac{2}{12}$ or $\frac{1}{6}$ for double thread

VII. Screw thread symbols (Transparencies 3 and 4)

A. Simplified

B. Schematic

C. Detailed

D. Combined

VIII. Classes of fit for unified threads and uses

A. Classes 1A and 1B--For parts that are easy to assemble; ordinance and other special uses; quick assembly

B. Classes 2A and 2B--For general purposes and most common uses

C. Classes 3A and 3B--For close tolerance screw thread

(NOTE: "A" refers to internal and "B" refers to external.)

INFORMATION SHEET

IX. Classes of fit for metric threads

  A. Coarse (general purpose)

  B. Fine

X. Parts of thread notes

  A. American National Screw Threads (Transparencies 5 and 6)

    1. Major diameter
    2. Threads per inch
    3. Profile
    4. Series
    5. Class of fit
    6. Left hand
    7. Thread depth

  B. American National Standard Unified (Transparency 7)

    1. Major diameter
    2. Threads per inch
    3. Series
    4. Class of fit
    5. Internal or external thread
    6. Left hand

  C. Metric thread (Transparency 8)

    1. Metric thread form
    2. Major diameter of thread
    3. Pitch
    4. Class of fit
    5. Internal-external
    6. Left hand

INFORMATION SHEET

XI. Conventional representations of pipe threads (Transparency 9)

   A. Schematic

   B. Simplified

XII. Types of threaded removable fasteners (Transparency 10)

   A. Bolts

   B. Studs

   C. Cap screws

   D. Machine screws

   E. Set screws

XIII. Shapes of bolts and nuts

   A. Square head

   B. Hexagon head

   (NOTE: Bolt specifications would include nominal size, thread type, length of bolt, finish of bolts, style of head, and name.)

XIV. Types of locknuts and locking devices (Transparency 11)

   A. Jam nuts

   B. Lock washer

   C. Cotter pin

   D. Set screw

   E. Hex slotted nut

   F. Hex castle nut

   G. Stop nut

   H. Elastic stop nut

   I. Spring head

   J. Wire rap nuts

   K. Serrated face nut

   L. Captive washer

INFORMATION SHEET

XV. Types of standard cap screws (Transparency 12)

- A. Hexagon head
- B. Flat head
- C. Round head
- D. Fillister head
- E. Hex socket head

XVI. Types of machine screws (Transparency 13)

- A. Round head
- B. Flat head
- C. Oval head
- D. Fillister head

XVII. Set screw heads and points (Transparency 14)

- A. Heads
  - 1. Slotted
  - 2. Hex socket
  - 3. Fluted socket
  - 4. Square
- B. Points
  - 1. Cup
  - 2. Flat
  - 3. Oval
  - 4. Full dog
  - 5. Half dog
  - 6. Cone

XVIII. Miscellaneous bolts and screws (Transparencies 15 and 16)

- A. Stove bolt
- B. Collar bolt
- C. Hanger bolt

INFORMATION SHEET

D. Step bolt

E. Track bolt

F. Square neck bolt

G. Fin neck bolt

H. Countersunk-square neck bolt

I. Ribbed neck bolt

J. Countersunk bolt

K. Roundhead bolt

L. Turnbuckle

M. Clevis

N. Thumb screw

O. Wing nut

P. T-head bolt

Q. Plow bolt

R. Eye bolt

S. U-bolt

T. Hook bolt

U. Askew-head bolt

V. J-bolt

W. Lag screw

X. Square head bolt

Y. Hexagon head bolt

Z. Aircraft bolt

AA. Lab bolt

BB. Tapping screw

CC. Tamper proof fasteners

  1. Spanner
  2. One way

INFORMATION SHEET

XIX. Standard large and small rivets

A. Standard large rivets (Transparency 17)

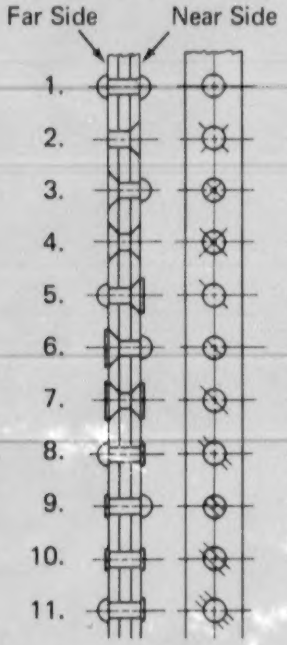
1. Button head
2. High button head (acorn)
3. Cone head
4. Pan head
5. Flat top countersunk head
6. Round top countersunk head

B. Small rivets (Transparency 18)

1. Pan head
2. Truss or wagon box head
3. Flat head
4. Countersunk head
5. Button head

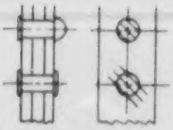
XX. Conventional rivet symbols and identification (Transparency 19)

A. Shop rivets



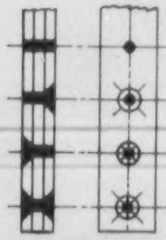
1. –Two full heads
2. --Countersunk and chipped; near side
3. --Countersunk and chipped; far side
4. --Countersunk and chipped; both sides
5. --Countersunk not over 1/8" high; near side
6. --Countersunk not over 1/8" high; far side
7. --Countersunk not over 1/8" high; both sides
8. --Flattened to 1/4", 1/2" and 5/8" rivets; near side
9. --Flattened to 1/4", 1/2" and 5/8" rivets; far side
10. --Flattened to 1/4", 1/2" and 5/8" rivets; both sides
11. --Flattened to 3/8", 3/4" rivets and over; near side

INFORMATION SHEET



12. --Flattened to 3/8", 3/4" rivets and over; far side
13. --Flattened to 3/8", 3/4" rivets and over; both sides

B. Field rivets



1. --Two full heads
2. --Countersunk; near side
3. --Countersunk; far side
4. --Countersunk; both sides

XXI. Advantages of plastic fasteners over metal fasteners

- A. Lightweight
- B. Thermal and electrical insulators
- C. Corrosion resistant
- D. Easy to color

XXII. Devices to lock components on a shaft (Transparencies 20 and 21)

- A. Sunk key (Pratt & Whitney)
- B. Woodruff key
- C. Square key
- D. Flat plain parallel key
- E. Square type taper key
- F. Flat type taper key
- G. Square gib head key
- H. Flat gib head key
- I. Taper pins
- J. Cotter key
- K. Retaining rings-internal
- L. Retaining rings-external
- M. Self-locking rings

INFORMATION SHEET

XXIII. Types of springs (Transparency 22)

- A. Compression (To absorb or cushion forces)
- B. Extension (Designed to stretch and pull back to original position)
- C. Torsion (Many different shapes that involve twisting)
- D. Flat (Any desired shape that absorbs energy)

XXIV. Notes and dimensions for types of springs (Transparency 23)

- A. Compression
  1. Free length
  2. Pitch
  3. Diameter ID or OD
  4. Type of end
  5. Direction of coil
  6. Material
  7. Wire gage
- B. Extension
  1. Length
  2. Free length
  3. Diameter OD
  4. Pitch
  5. Direction of coil
  6. Material
  7. Wire gage
- C. Torsion
  1. Length
  2. Number of coils
  3. Diameter of wire OD
  4. Type of end
  5. Length of end and angle

INFORMATION SHEET

6. Direction of coil
7. Material
8. Gage

XXV. Types of spring clips (Transparency 24)

A. Spring molding
B. Stud receiver
C. Cable, wire, and tube
D. Dart-type
E. U-shaped, S-shaped, and C-shaped

XXVI. Types of keys to prevent relative motion between wheel and shaft (Transparency 25)

A. Square
B. Flat
C. Gib head
D. Pratt and Whitney
E. Woodruff
F. Round

(NOTE: Keys are ordered by size except Woodruff keys which are ordered by number.)

XXVII. Types of machine pins (Transparency 26)

A. Dowel
B. Tapered
C. Clevis
D. Spirally coiled
E. Grooved
F. Knurled
G. Quick release
H. Cotter
I. Wire

INFORMATION SHEET

J. Split

K. Drive

XXVIII. Washers (Transparency 27)

A. Flat washers--Bearing surface

(NOTE: The two types include heavy and standard.)

B. Conical washers--Spring action

C. Helical spring washers--Locking

D. Tooth lock washers--Locking

E. Spring washers--Built-in pressure

F. Special purpose washers--Decoration and other functions

(NOTE: These are available in plated and unplated finishes.)

XXIX. Applications of inserts

A. In light alloys and plastics for higher strength

B. In ferrous alloys for permanent threads

C. In thin parts for internal locking of threaded holes

D. In reassembly of mating screw without damage to metal

XXX. Types of lock washers (Transparency 28)

A. Helical spring

1. Plain
2. Nonlink positive

B. Tooth lock

1. Internal
2. External
3. Countersunk
4. External-internal
5. Dome
6. Dished
7. Pyramidal

INFORMATION SHEET

XXXI. Uses for spring washer designs

- A. Provide pressure on adjacent parts
- B. Act as take-up devices in an assembly
- C. Control end pressure
- D. Eliminate end play

XXXII. Quick opening and locking devices (Transparency 29)

- A. Link lock
- B. Hinge lock
- C. Hook lock
- D. Quarter turn
- E. Spring lock
- F. Trigger lock

XXXIII. Miscellaneous machine elements and uses

- A. Quick release pins--To rapidly assemble and disassemble parts
- B. Resistance welded fasteners (Transparency 30)
  - 1. Projection weld--To weld nuts to a surface
  - 2. Spot weld--To weld studs to a surface
- C. Stud welded fasteners--To prevent leaks at joints
- D. Self-tapping screws--To cut mating thread in metal or plastic
- E. Captive nuts--To prevent rotation of nuts
- F. Wing nuts--To allow fastening with fingers
- G. Screw and washer assembles--To save time at assembly

XXXIV. Advantages of welding over threaded fasteners (Transparency 31)

- A. Fast and relatively simple process
- B. Savings in time and expense
- C. Less weight than casting or forged part in most cases
- D. Neater appearance
- E. Less noisy

INFORMATION SHEET

- F. Painting simplified
- G. Small quantity jobs

XXXV. Types of welded joints (Transparency 32)

- A. Lap
- B. Butt
- C. Tee
- D. Corner
- E. Edge

XXXVI. Parts of a welding symbol (Transparency 33)

- A. Finish symbol
- B. Contour symbol
- C. Groove angle
- D. Specification, process, or other reference
- E. Tail

  (NOTE: This may be omitted when a reference is not used.)
- F. Reference line
- G. Size or strength for certain welds
- H. Basic weld symbol
- I. Root opening, depth of filling for certain welds
- J. Number of spot or projection welds
- K. Length of welds
- L. Pitch of welds
- M. Weld-all-around symbol
- N. Field weld symbol
- O. Arrow
- P. Multiple welds

INFORMATION SHEET

XXXVII. Basic arc and gas weld symbols (Transparency 34)

- A. Fillet
- B. Plug or slot
- C. Arc-spot or arc-seam
- D. Groove
  - 1. Square
  - 2. V
  - 3. Bevel
  - 4. U
  - 5. J
  - 6. Flare V
  - 7. Flare bevel
- E. Back or backing
- F. Surfacing
- G. Flange
  - 1. Edge
  - 2. Corner

XXXVIII. Supplementary welding symbols (Transparency 35)

- A. Weld-all-around
- B. Field weld
- C. Contour
  - 1. Flush
  - 2. Convex
- D. Melt thru

XXXIX. Dimensioning of welds (Transparency 36)

- A. Weld-all-around
- B. Staggered

INFORMATION SHEET

C. Near side-opposite side

D. Combined welds

XL. Resistance welding symbols (Transparency 37)

(NOTE: Students will be responsible for new symbols.)

A. Resistance spot

B. Projection

C. Resistance seam

D. Flash or upset

XLI. Classifications of methods of using adhesives for bonding materials

A. Functional

1. Structural
2. Holding
3. Sealing

B. Chemical

1. Thermosetting
2. Thermoplastic
3. Repetitive structure
    a. Epoxies
    b. Polyamides
    c. Polyurethanes
    d. Polyacrylates

C. Method of application

1. Solvent
2. Hot melt
3. Two part

INFORMATION SHEET

D. Nature of properties

  1. Metal to metal
  2. Metal to plastic
  3. Plastic to glass

XLII. Joint design considerations for adhesive bonding

A. Consider type of stresses on bonded joint (Transparency 38)

Example: Shear, tension, compression, cleavage, and peel

B. Use as large of contact areas as possible for maximum strength

XLIII. Joint designs for adhesive bonding (Transparency 39)

A. Lap joint

B. Joggle joint

C. Double butt lap

D. Tapered lap

E. Double scarf lap

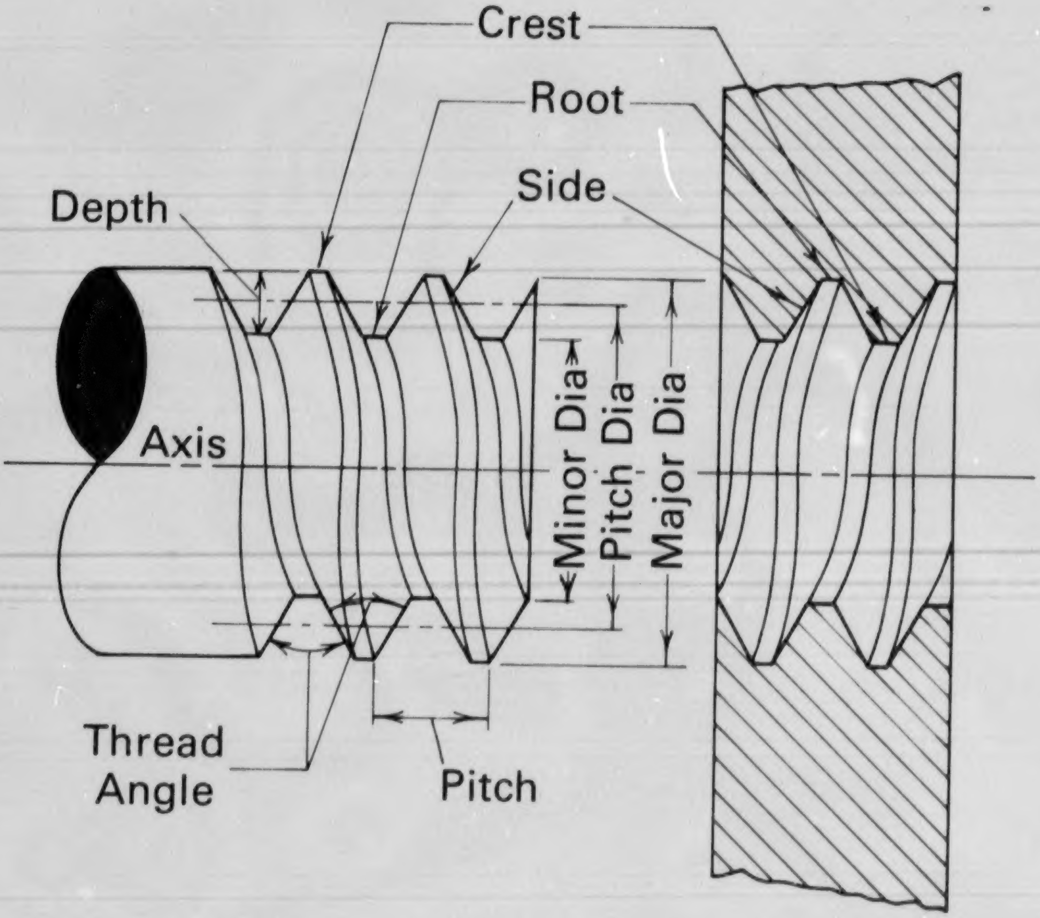
F. Corner joint

G. T-section stiffener

H. End lap joint

I. Mortise and tenon

Screw Thread Nomenclature

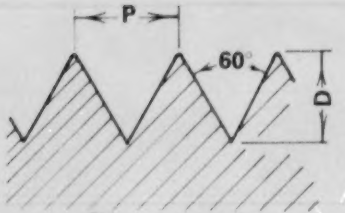

Crest
Root
Side
Depth
Axis
Minor Dia
Pitch Dia
Major Dia
Thread Angle
Pitch

External Thread

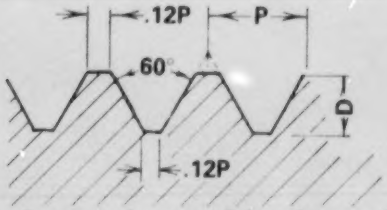
Internal Thread

$$\text{Pitch} = \frac{1}{\text{Number of Threads Per Inch}}$$

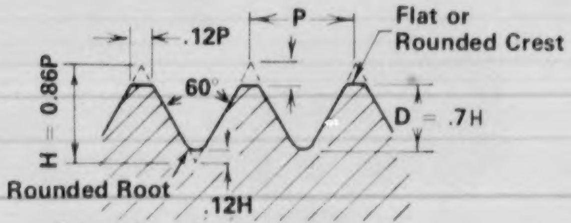
Screw Thread Profiles



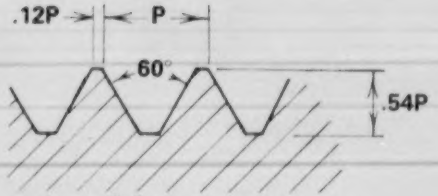
Sharp V


.12P
P
60°
D
.12P

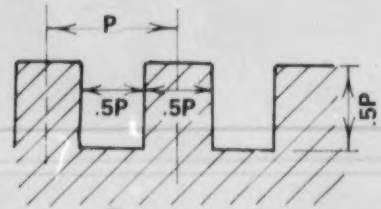
American National


.12P
P
Flat or
Rounded Crest
H = 0.86P
60°
D = .7H
Rounded Root
.12H

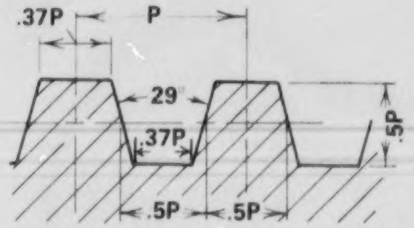
Unified (External)



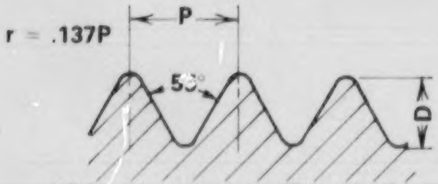
Metric



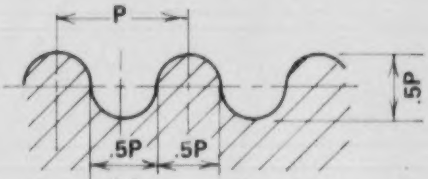
Square


.37P
P
29°
.37P
.5P
.5P
.5P

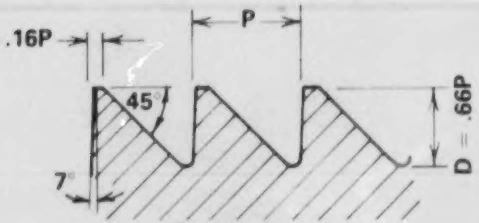
General Purpose Acme



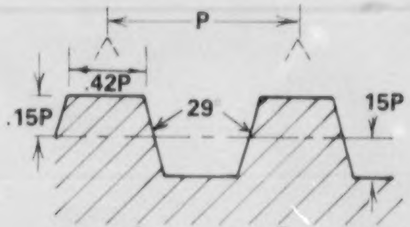
Whitworth Standard



Knuckle


.16P
P
45°
D = .66P
7°

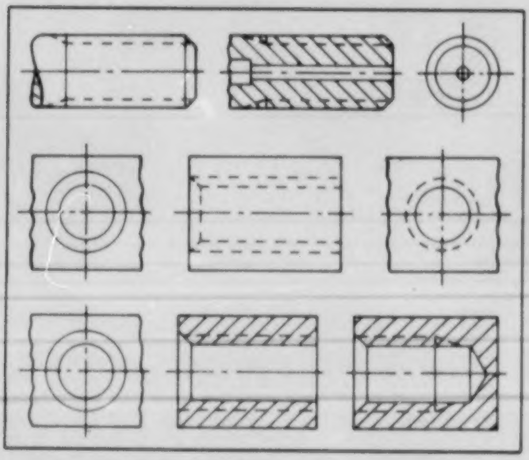
Buttress


P
.42P
.15P
29°
15P

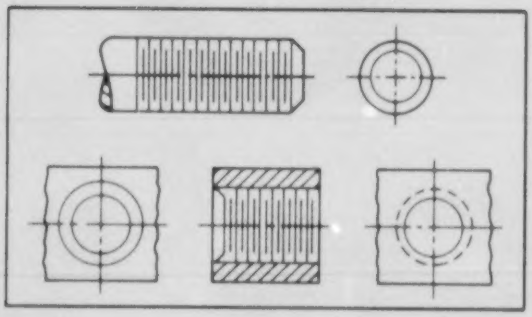
Acme--Stub

(NOTE: Dimensions may be used to approximate the threads for detail drawings.)

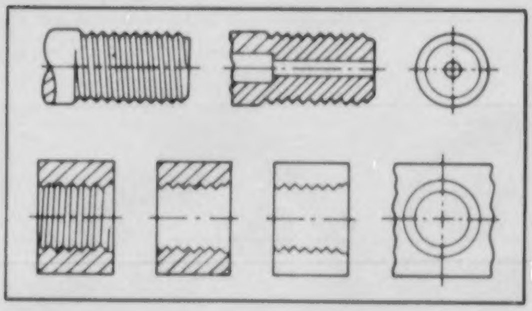
Screw Thread Symbols



Simplified Representation of Threads



Schematic Representation of Threads



Detailed Representation of Threads

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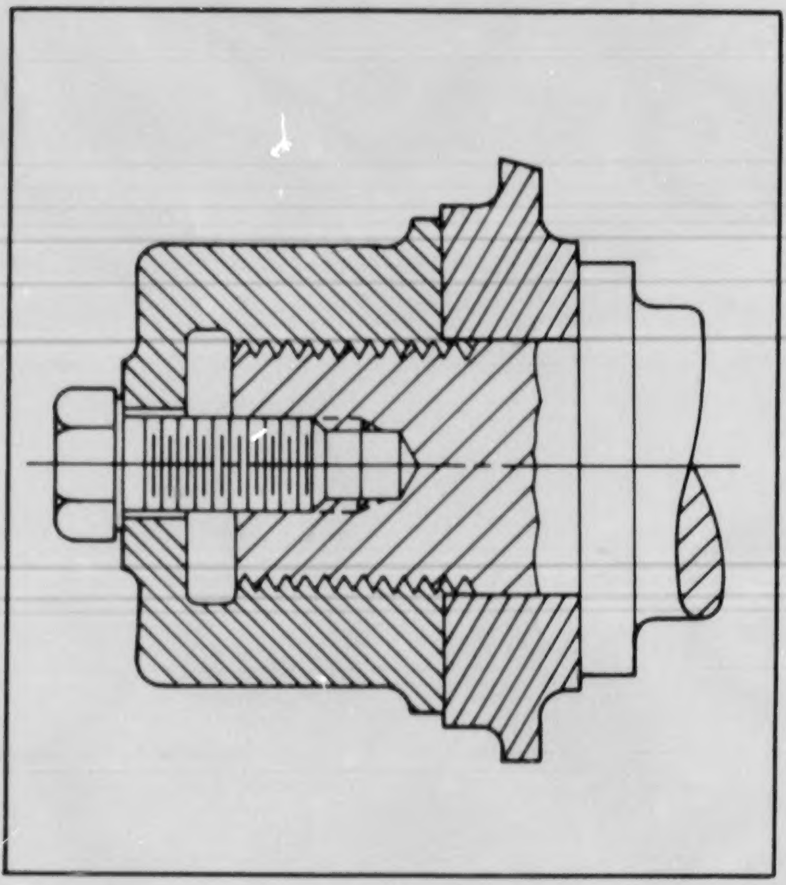
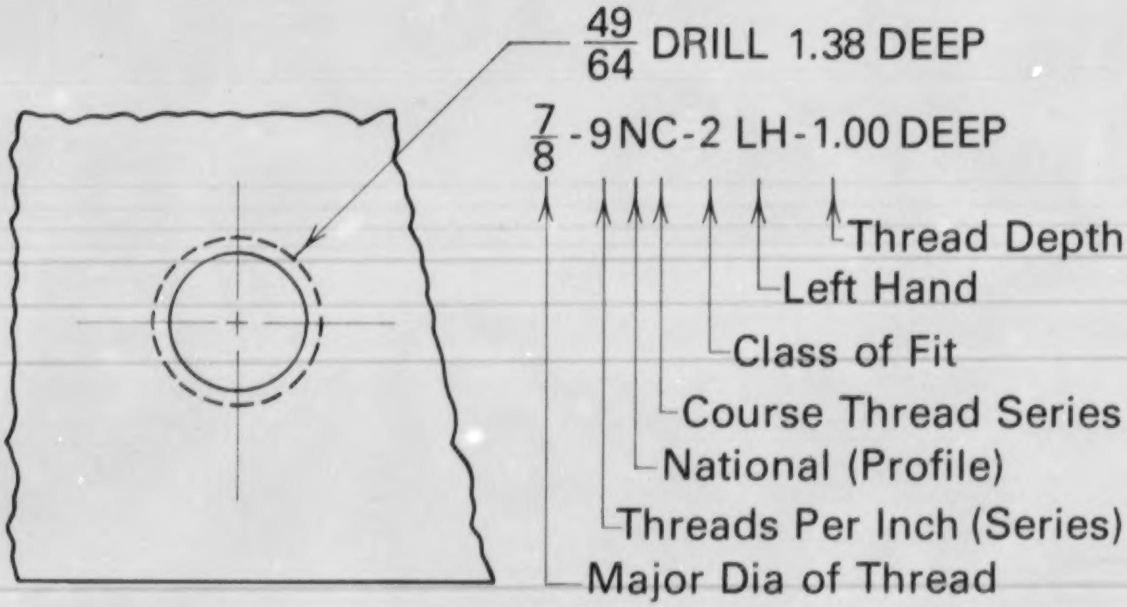
Combined Screw Thread Symbols

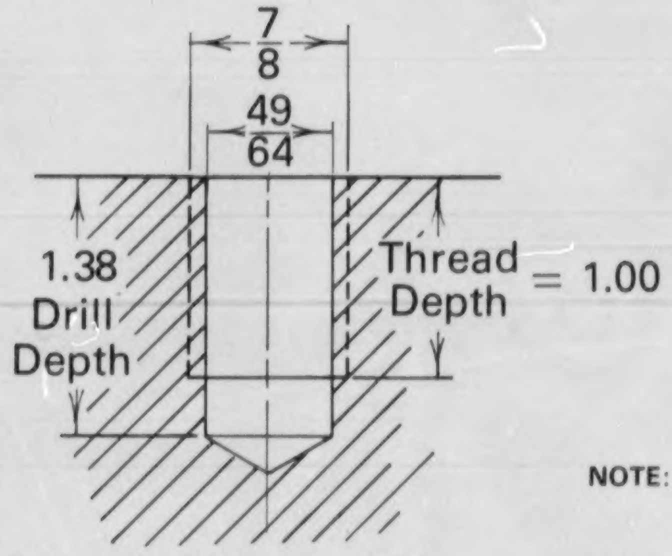


Multiple Thread Representations of Assembled Parts

From ANSI 14.6-1978 Reprinted with permission of ASME

American National Thread Note for Holes

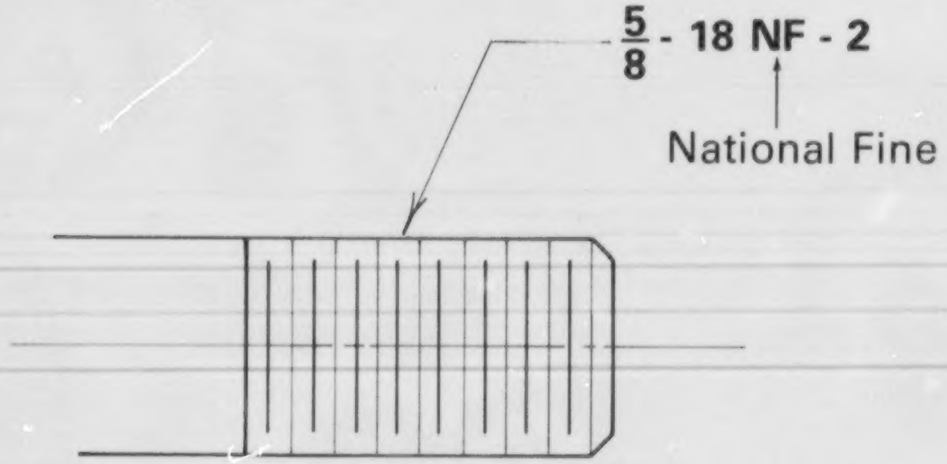

49/64 DRILL 1.38 DEEP
7/8 - 9NC-2 LH-1.00 DEEP
Thread Depth
Left Hand
Class of Fit
Course Thread Series
National (Profile)
Threads Per Inch (Series)
Major Dia of Thread

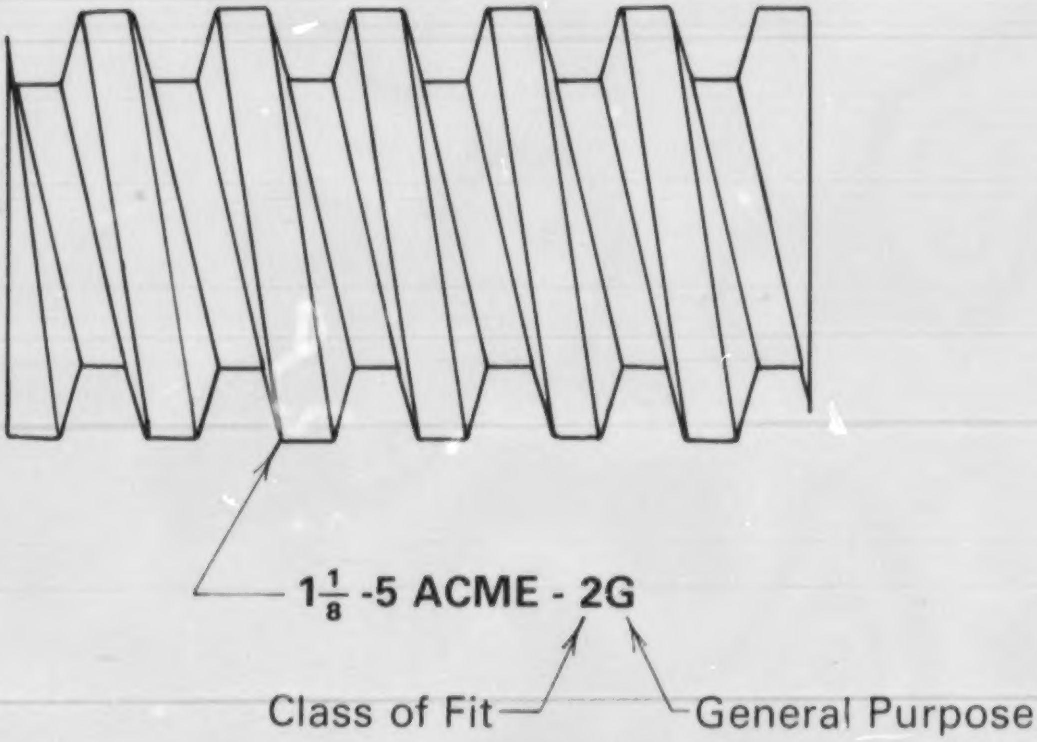

7/8
49/64
1.38 Drill Depth
Thread Depth = 1.00

Interpretation of Note

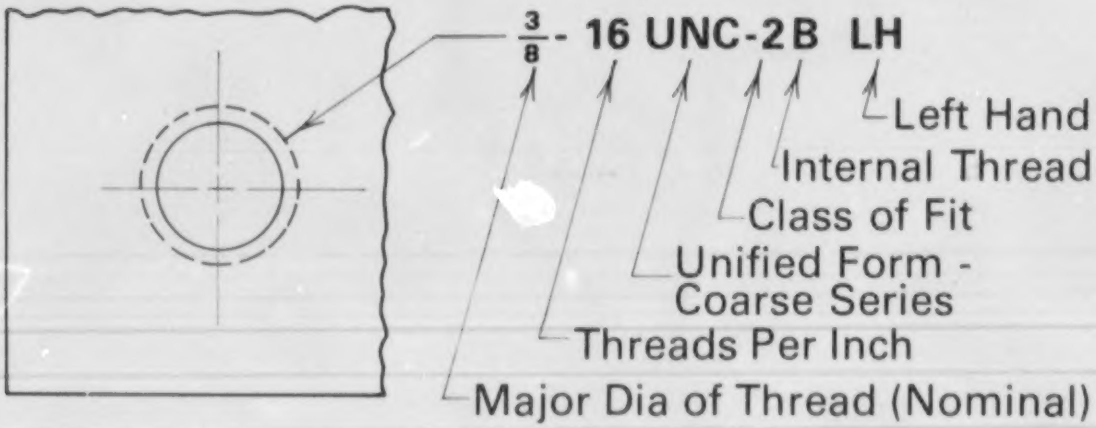
NOTE: Obtain tap drill size from thread chart.

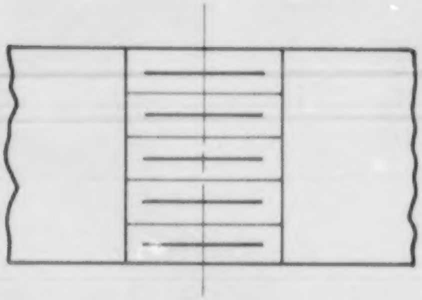
American National Thread Notes for Threaded Shaft

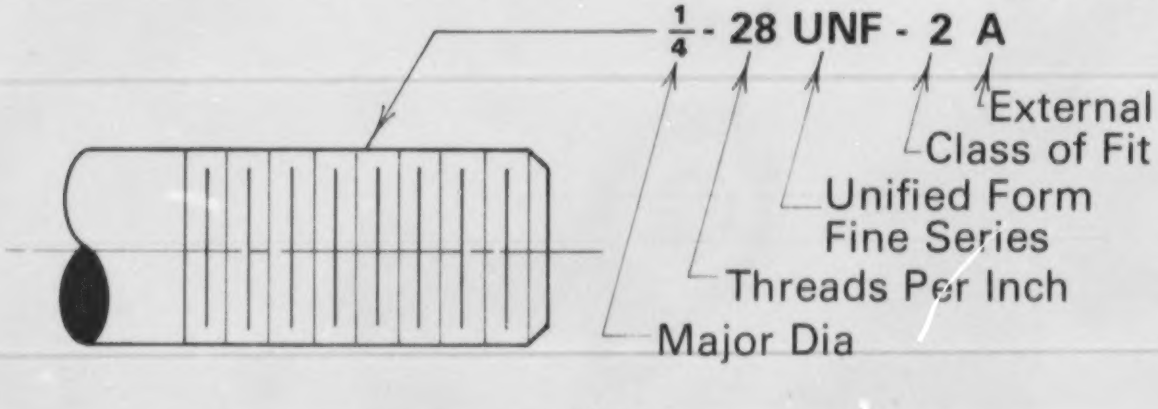

$\frac{5}{8}$ - 18 NF - 2
National Fine


$1\frac{1}{8}$ -5 ACME - 2G
Class of Fit
General Purpose

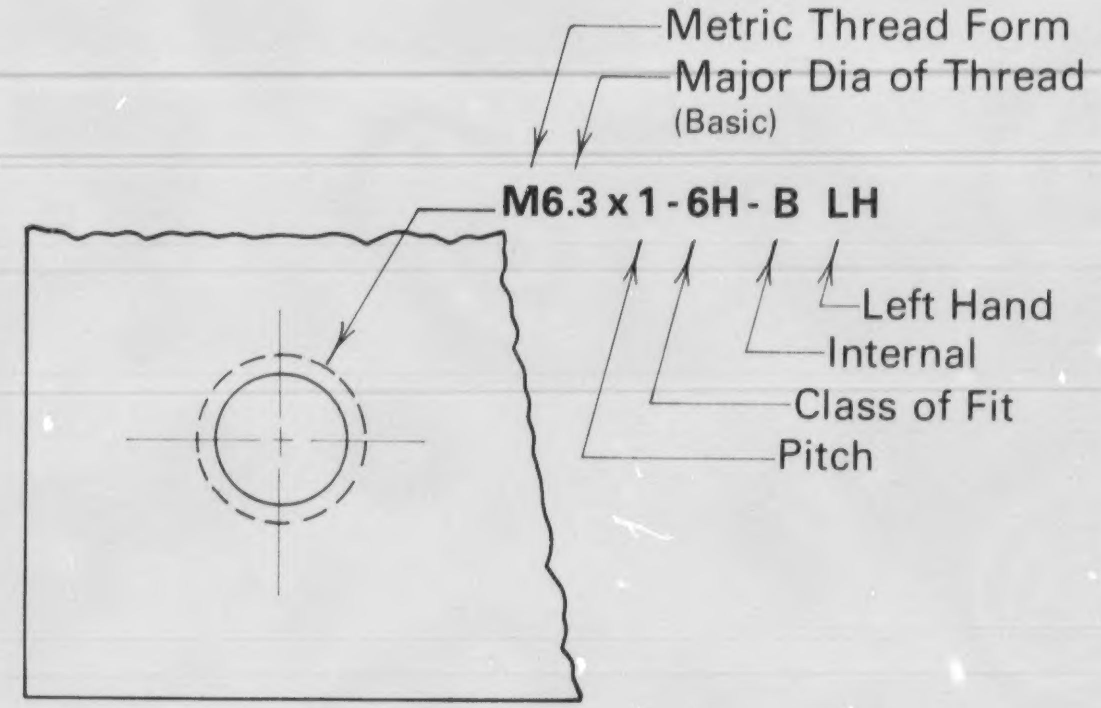
American Standard Unified Thread Notes


$\frac{3}{8}$ - 16 UNC-2B LH
Left Hand
Internal Thread
Class of Fit
Unified Form - Coarse Series
Threads Per Inch
Major Dia of Thread (Nominal)




$\frac{1}{4}$ - 28 UNF - 2 A
External
Class of Fit
Unified Form Fine Series
Threads Per Inch
Major Dia

Metric Thread Notes



Metric Thread Form

Major Dia of Thread (Basic)

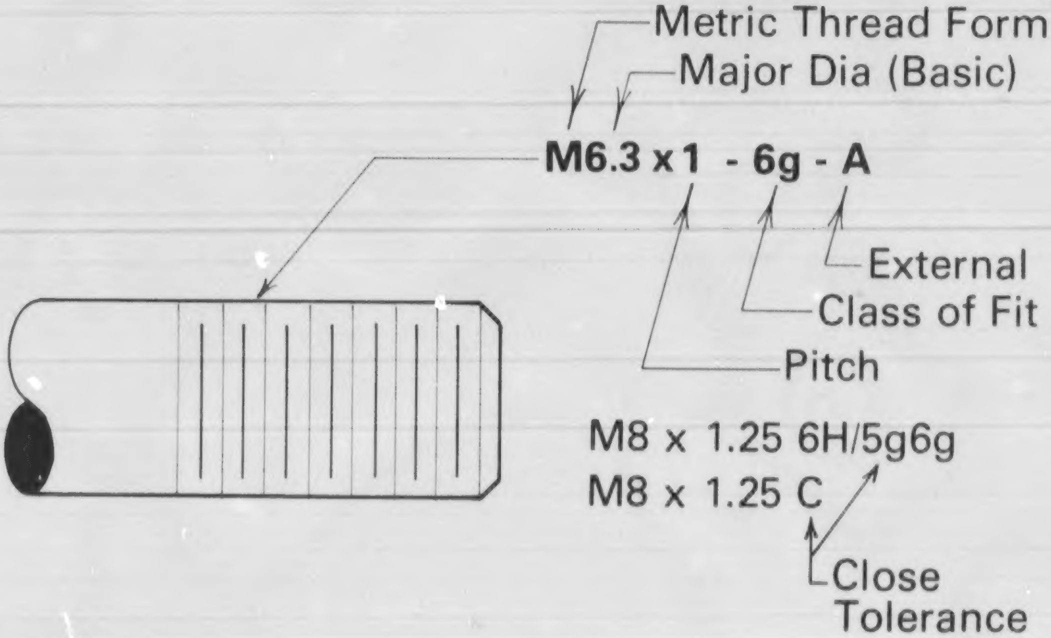
M6.3 x 1 - 6H - B LH

Left Hand

Internal

Class of Fit

Pitch



Metric Thread Form

Major Dia (Basic)

M6.3 x 1 - 6g - A

External

Class of Fit

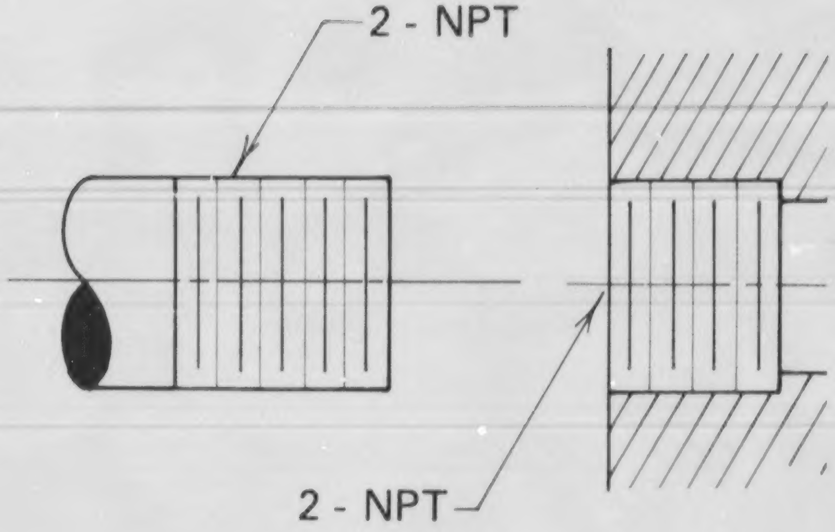
Pitch

M8 x 1.25 6H/5g6g

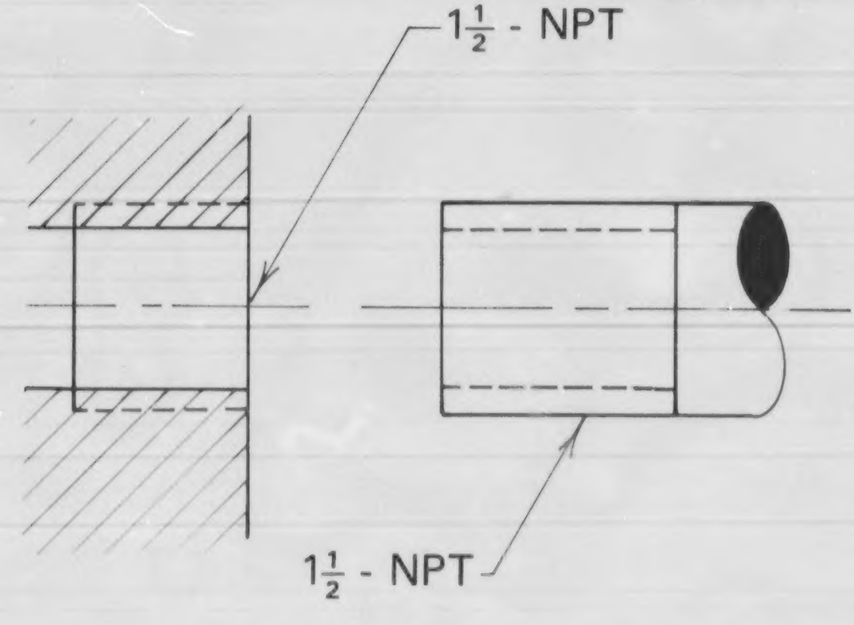
M8 x 1.25 C

Close Tolerance

Pipe Threads

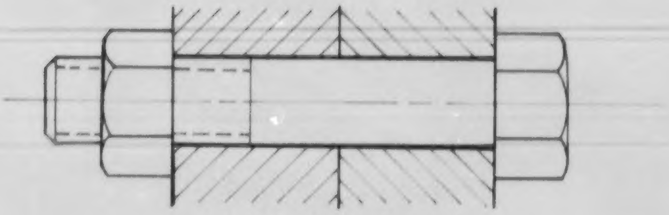


Schematic

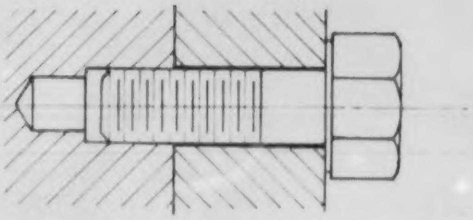

1½ - NPT
1½ - NPT

Simplified

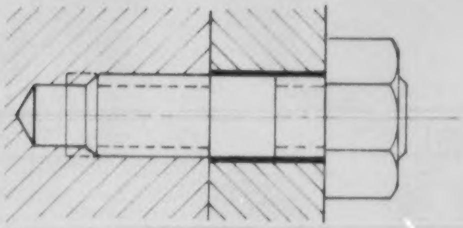
Removable Fasteners



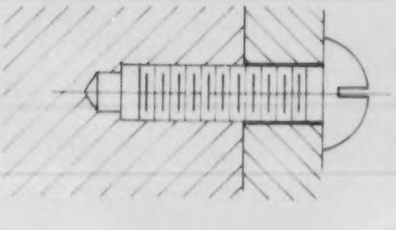
Bolt



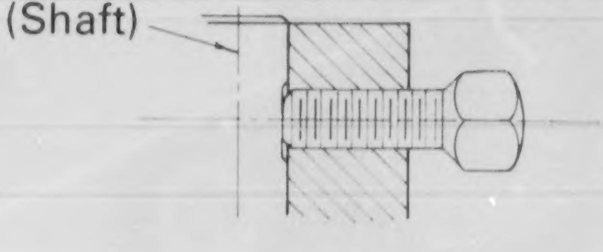
Cap Screw



Stud

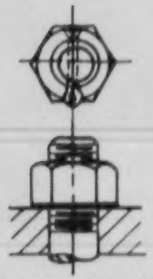


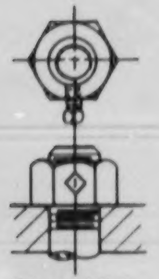
Machine Screw

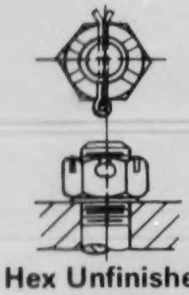


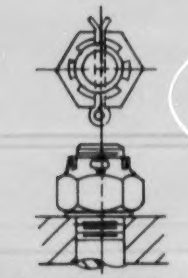
Set Screw

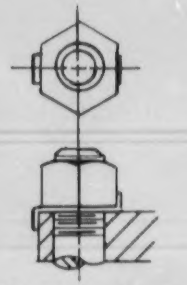
Locknuts and Locking Devices

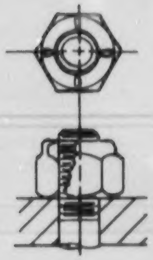

Cotter Pin Hex Semi-Finished Thick Nut

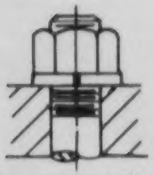

Nut With Set Screw

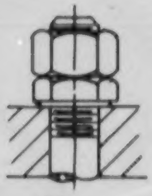

Hex Unfinished Slotted Nut With Cotter Pin

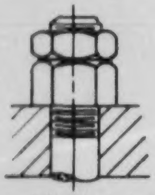

Semi-Finished Castle Nut With Cotter Pin

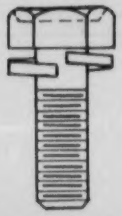

Hexagon Nut with Lock

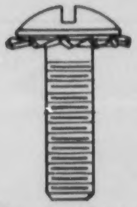

Stop Nut

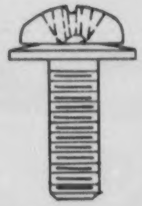

Lock Washer


Hex Semi-Finished Jam Nut


Hex Unfinished Jam Nut


Hexagon Head Screw and Spring Lock Washer


Truss Head Screw and External Tooth Lock Washer


Pan Head Screw and Conical Spring Washer

Screw and Washer Assemblies

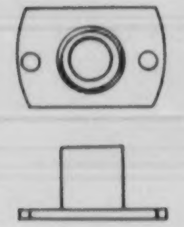
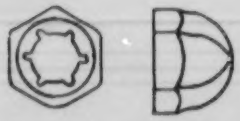
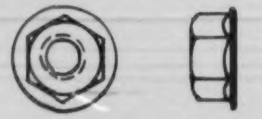
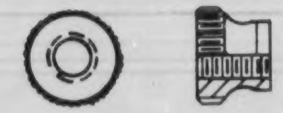
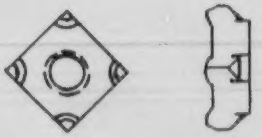


Plate Nut

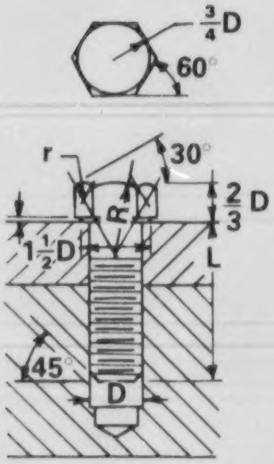

Stamped Nut


Flange Nut

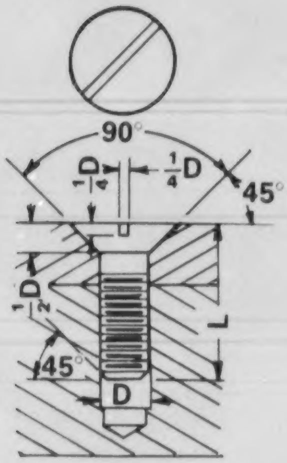

Knurled Nut


Weld Nut

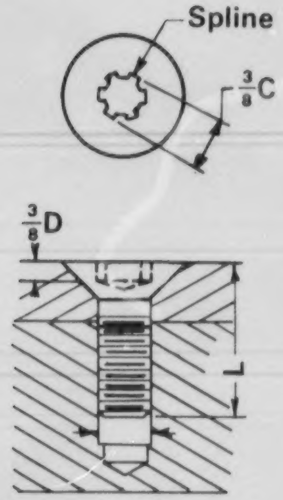
Standard Cap Screws


$\frac{3}{4}$D
60°
30°
r
R
$\frac{2}{3}$ D
$1\frac{1}{2}$D
L
45°
D

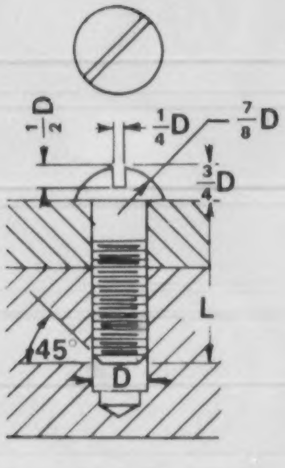
Hexagon Head


90°
$\frac{1}{4}$D
$\frac{1}{4}$D
45°
$\frac{1}{2}$D
L
45°
D

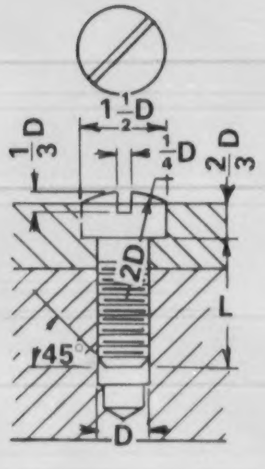
Flat Head


Spline
$\frac{3}{8}$C
$\frac{3}{8}$D
L

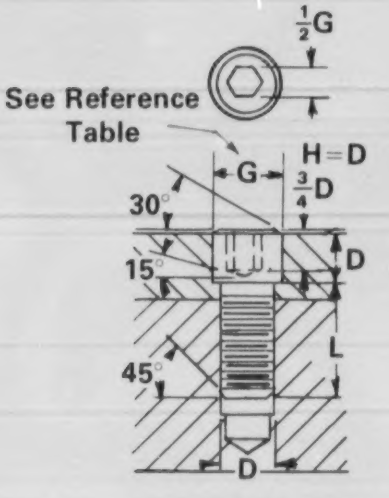
Spline Socket
Flat Head


$\frac{1}{2}$D
$\frac{1}{4}$D
$\frac{7}{8}$D
$\frac{3}{4}$D
L
45°
D

Round Head


$1\frac{1}{2}$D
$\frac{1}{3}$D
$\frac{1}{4}$D
$\frac{2}{3}$D
2D
L
45°
D

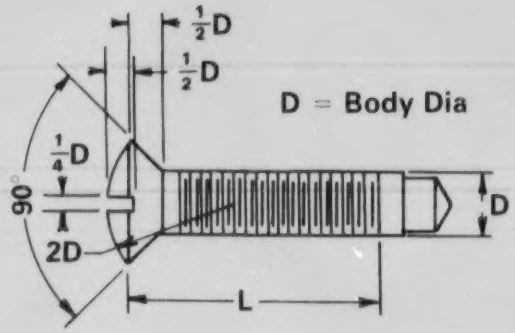
Fillister Head


$\frac{1}{2}$G
See Reference Table
G
H=D
$\frac{3}{4}$D
30°
15°
D
L
45°
D

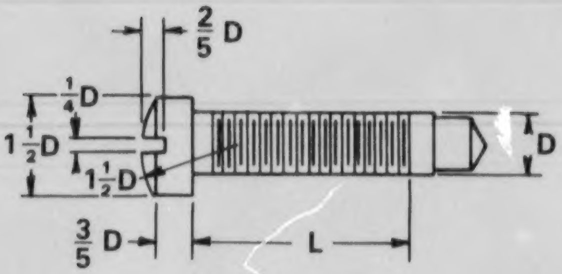
Hex Socket

Machine Screws

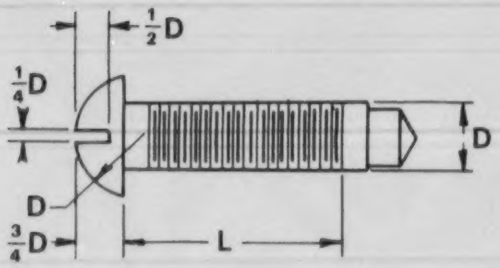
D = Body Dia


½D
½D
¼D
90°
D
2D
L

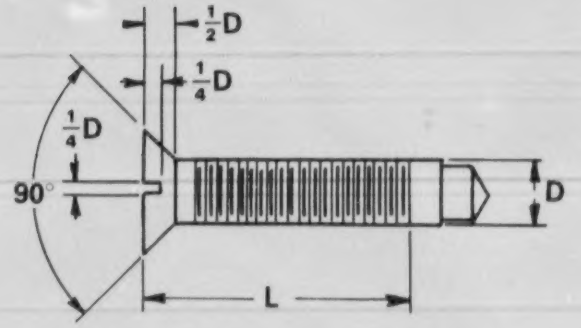
Oval Head


⅖ D
¼D
1½D
1½D
D
⅗ D
L

Fillister Head



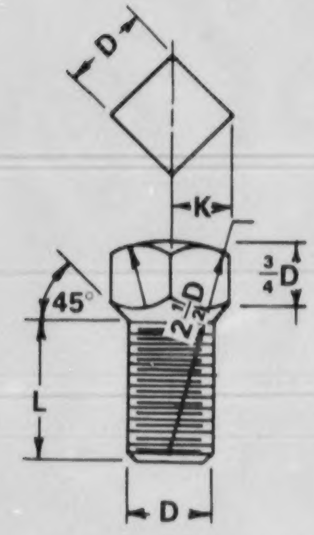
Round Head


½D
¼D
¼D
90°
D
L

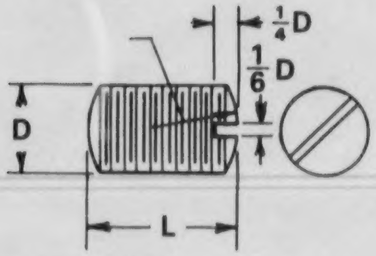
Flat Head

(NOTE: These are approximate dimensions for drawing purposes. Use hardware catalog for accurate dimensions.)

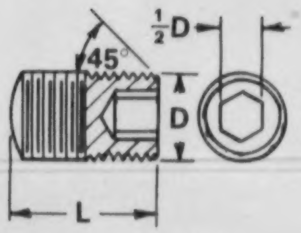
Set Screws


D
K
$\frac{3}{4}D$
45°
$2\frac{1}{2}D$
L
D

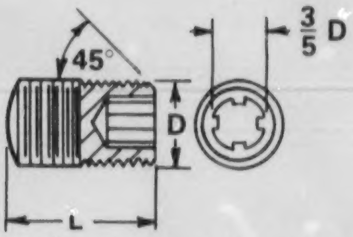
Square Head


$\frac{1}{4}D$
$\frac{1}{6}D$
D
L

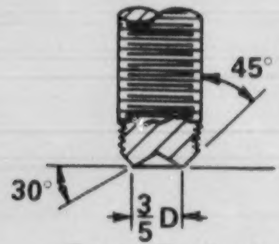
Slotted


$\frac{1}{2}D$
45°
D
L

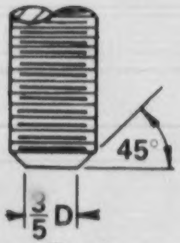
Hex Socket


45°
$\frac{3}{5}D$
D
L

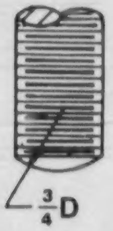
Socket Spline


45°
30°
$\frac{3}{5}D$

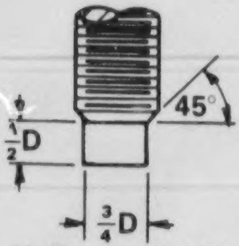
Cup Point



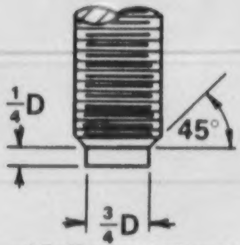
Flat Point



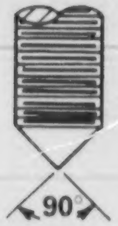
Oval Point


45°
$\frac{1}{2}D$
$\frac{3}{4}D$

Full Dog Point


$\frac{1}{4}D$
45°
$\frac{3}{4}D$

Half Dog Point

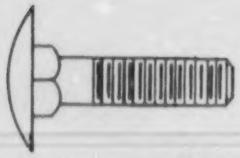


Cone Point

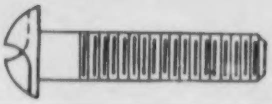
D = Thread Diameter
L = Length

(NOTE: These are approximate dimensions for drawing purposes. Use hardware or standards catalogs for accurate dimensions.)

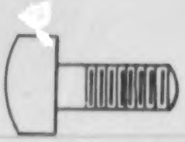
Miscellaneous Bolts and Screws



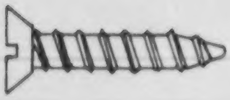
Step Bolt



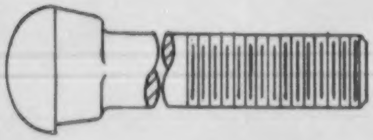
One-Way Head Screw



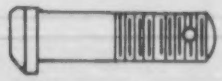
Meter Bolt



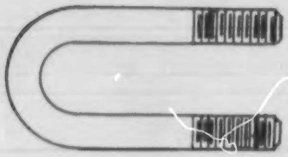
Tapping Screw



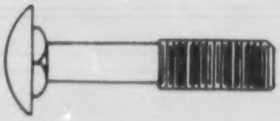
Oval Head Truck Bolt



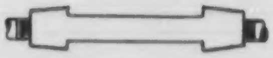
Connecting Rod Bolt



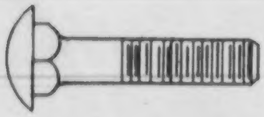
U-Bolt, Round Bend



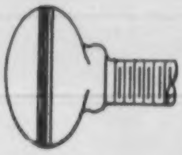
Round Head Short Square Neck Bolt



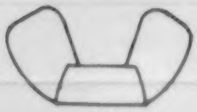
Turnbuckle



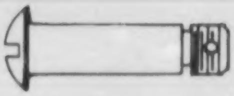
Round Head Square Neck Bolt



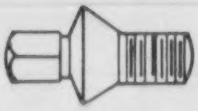
Thumb Screw



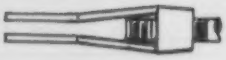
Wing Nut



Clevis Bolt



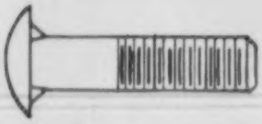
Boiler Patch Bolt



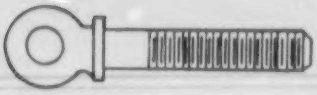
Clevis

Miscellaneous Bolts and Screws

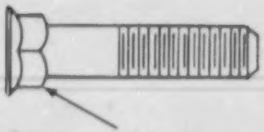
(Continued)



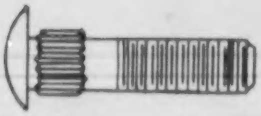
Round Head Fin Neck Bolt



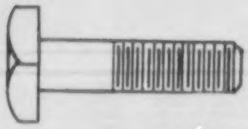
Collared Eye Bolt



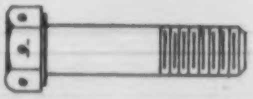
Square Neck



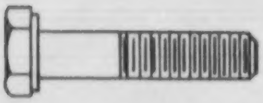
Round Head Ribbed Neck Bolt



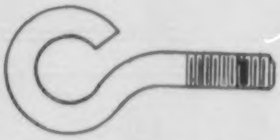
Square Head Bolt



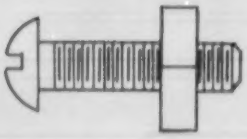
Aircraft Drilled Head Bolt



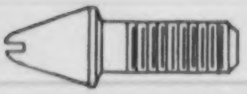
Hexagon Head



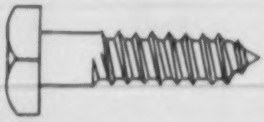
Eye Bolt, Open Anchor Ring



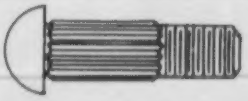
Stove Bolt



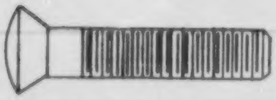
Hood Latch Bolt



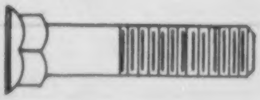
Lag Bolt



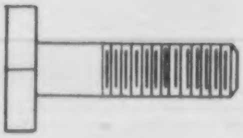
Rivet Bolt



Strut Bolt

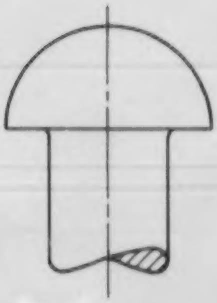


Round Countersunk Head Square Neck Plow Bolt

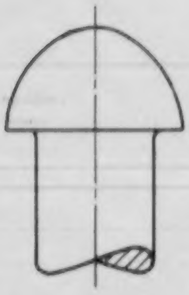


T-Bolt

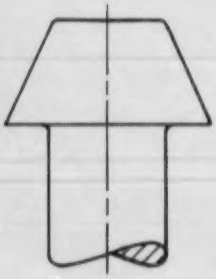
Standard Large Rivets



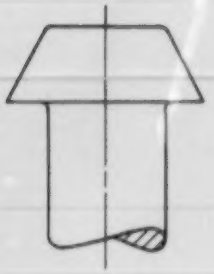
Button Head



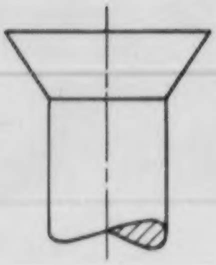
High Button Head (Acorn)



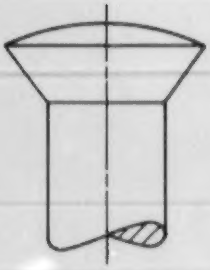
Cone Head)



Pan Head

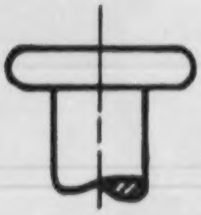


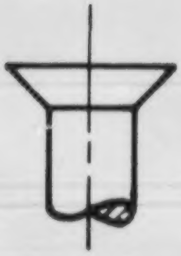
Flat Top Countersunk HD

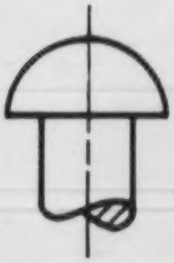


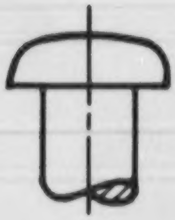
Round Top Countersunk HD

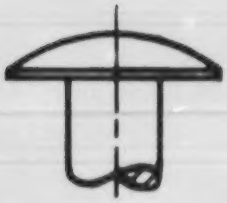
Small Rivets


Flat
Head

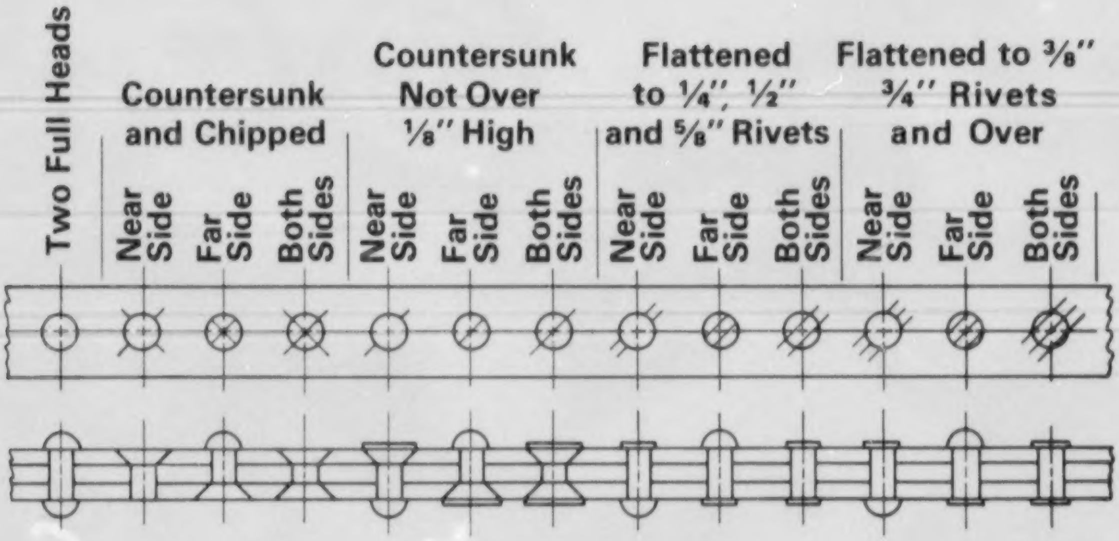

Countersunk
Head


Button
Head

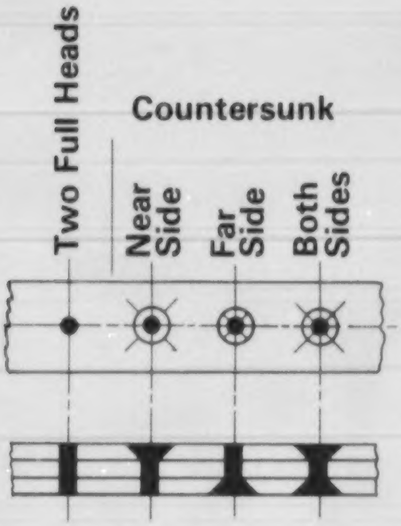

Pan
Head


Truss or
Wagon
Box Head

Rivet Symbols

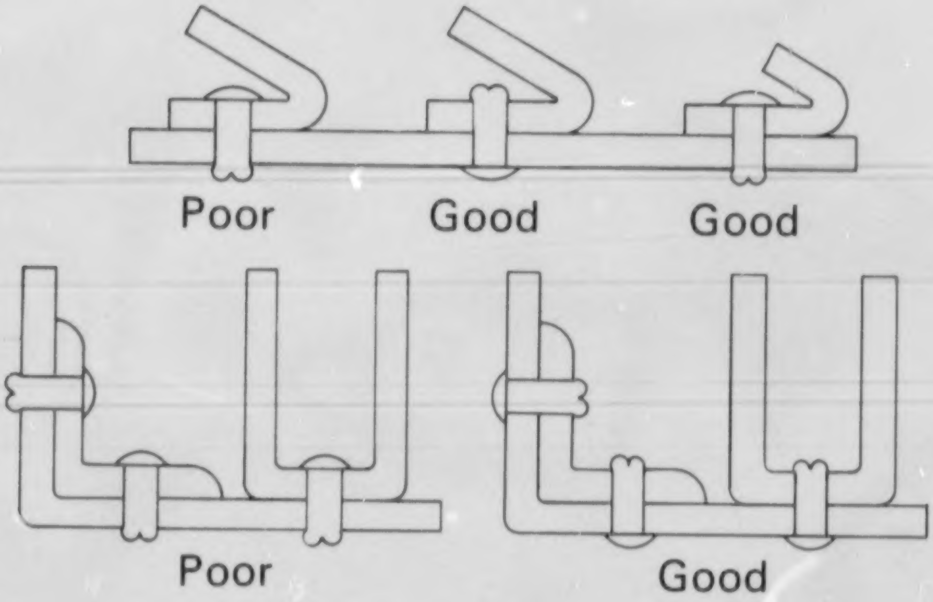

Two Full Heads
Countersunk and Chipped
Near Side
Far Side
Both Sides
Countersunk Not Over ⅛" High
Near Side
Far Side
Both Sides
Flattened to ¼", ½" and ⅝" Rivets
Near Side
Far Side
Both Sides
Flattened to ⅜" ¾" Rivets and Over
Near Side
Far Side
Both Sides

Shop Rivets

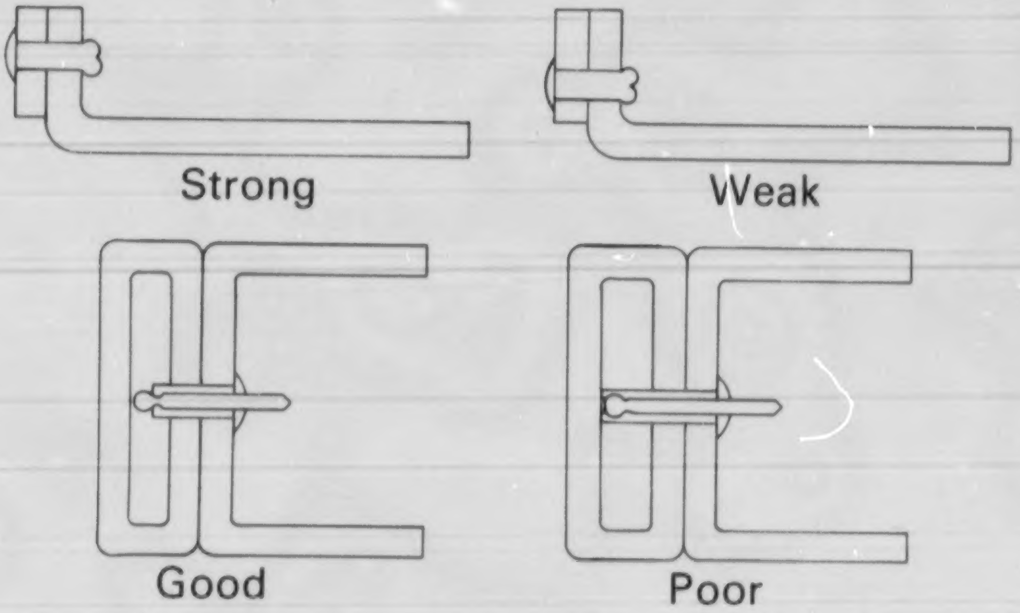

Two Full Heads
Countersunk
Near Side
Far Side
Both Sides

Field Rivets

Design with Rivets

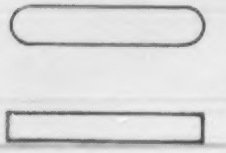

Poor
Good
Good
Poor
Good

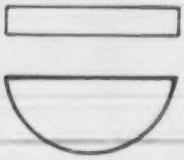
Clearance Problems


Strong
Weak
Good
Poor

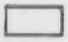
Placement Problems

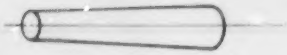
Shaft Locking Hardware

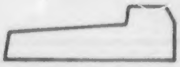

Round End Key
(Pratt and Whitney)

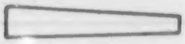

Woodruff
Key

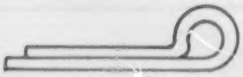
Square
Key

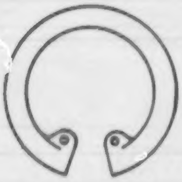

Flat
Key

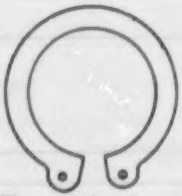

Taper
Key

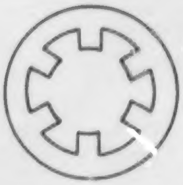

Gib Head
Key

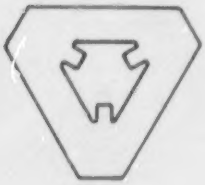

Taper
Pin

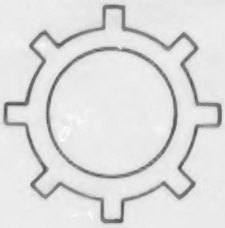

Cotter Pin


Retaining
Ring
Internal

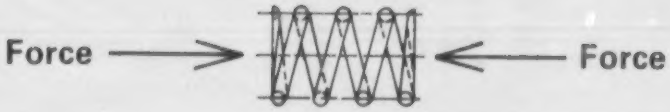

Retaining
Ring
External


Self Locking
External

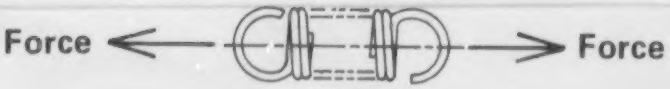

Self Locking
Triangular


Self Locking
Internal

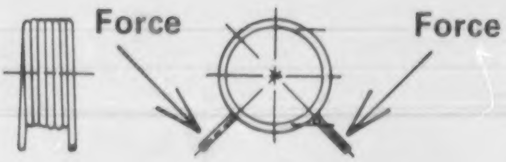
Springs


Force
Force

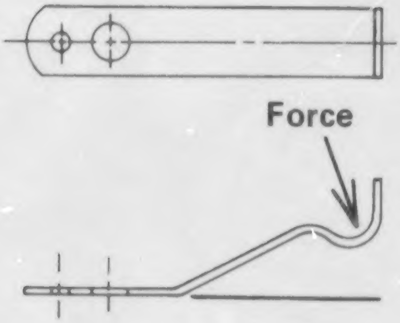
Compression


Force
Force

Extension

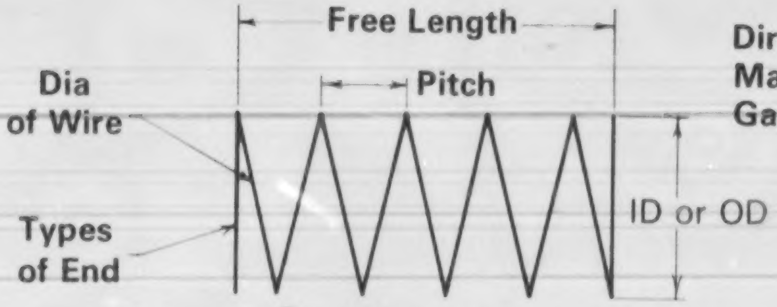

Force
Force

Torsion



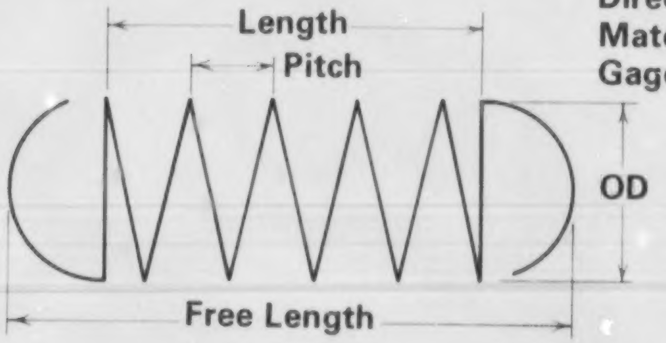
Flat

Schematic Spring Drawing Representative


Free Length
Pitch
Dia of Wire
Types of End
ID or OD

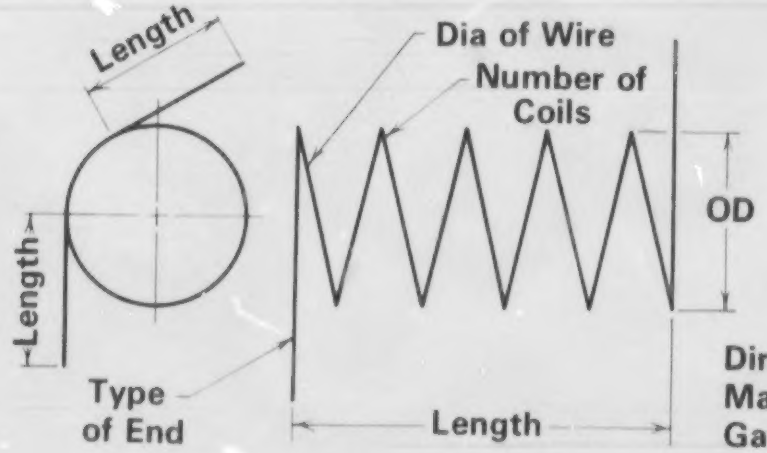
Direction of Coil _____
Material _____
Gage _____

Compression


Length
Pitch
OD
Free Length

Direction of Coil _____
Material _____
Gage _____

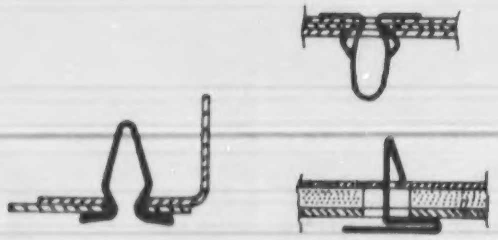
Extension


Length
Dia of Wire
Number of Coils
OD
Length
Type of End
Length

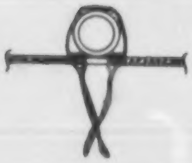
Direction of Coil _____
Material _____
Gage _____

Torsional

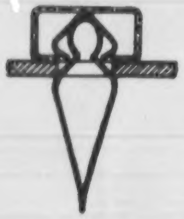
Clips



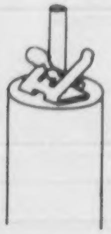
Dart Type Spring Clips



Cable, Wire,
and Tubing Clips

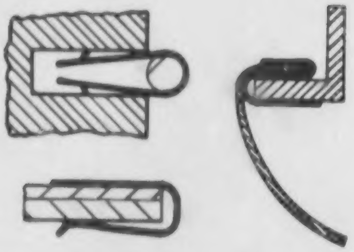


Spring
Molding Clip



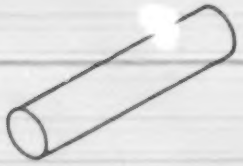
Stud Receiver
Clips

Note: These must be identified by using vendors catalog.

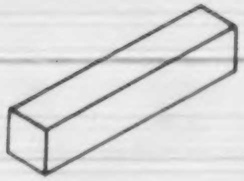


"U"-Shaped, "S"-Shaped
and "C"-Shaped Clips

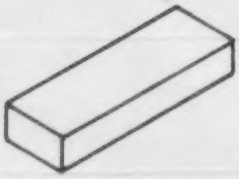
Keys



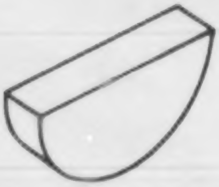
Round



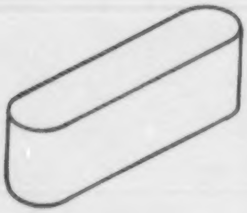
Square



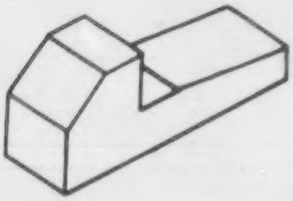
Flat



Woodruff

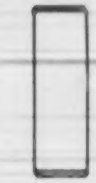


Pratt and Whitney

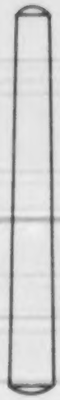


Gib Head

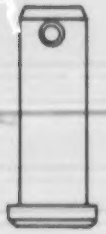
Pins



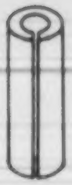
Dowel



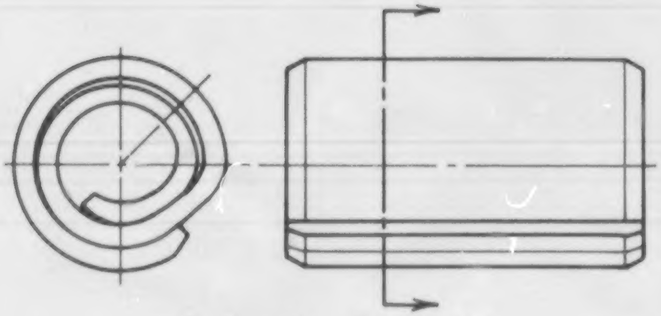
Tapered



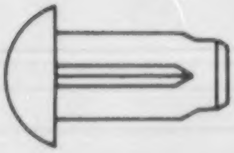
Clevis



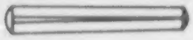
Split



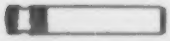
Spirally Coiled



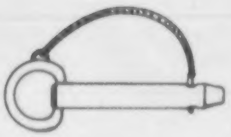
Drive



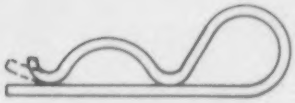
Grooved



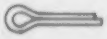
Knurled



Quick Release

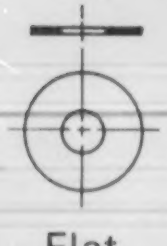


Wire

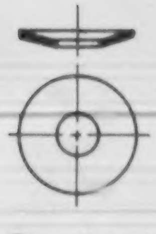


Cotter

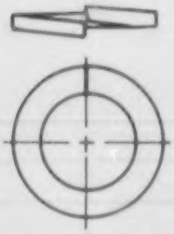
Washers



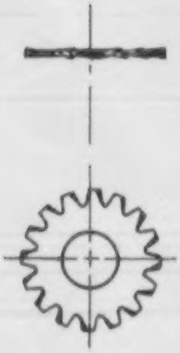
Flat



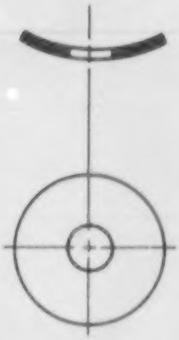
Conical



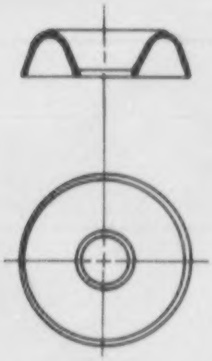
Helical Spring



Tooth Lock

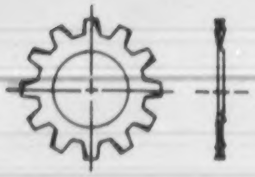


Spring Type

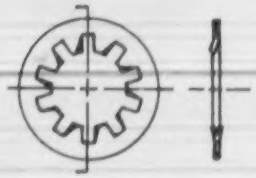


Finishing

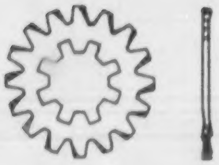
Tooth Lock Washers



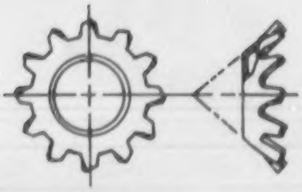
External



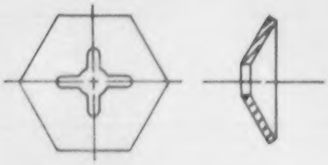
Internal



External-Internal

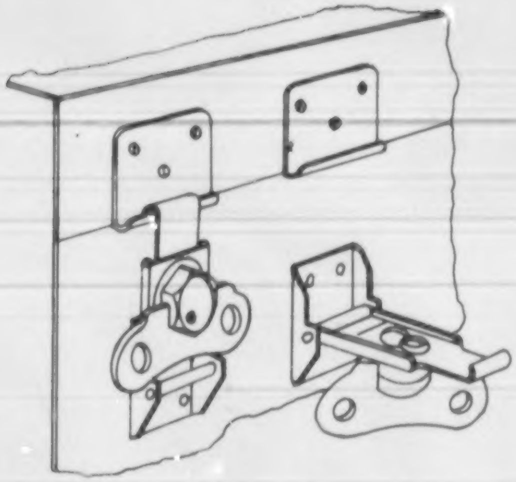


Countersunk

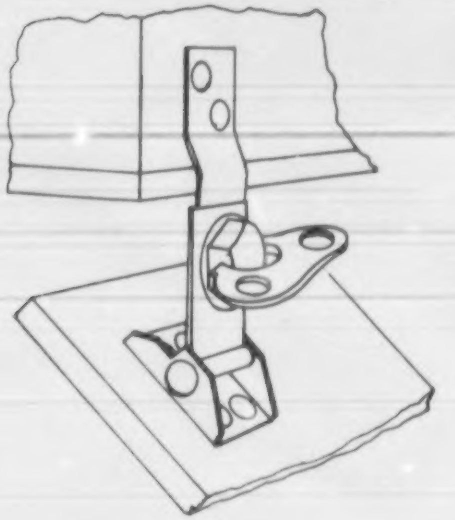


Pyramidal

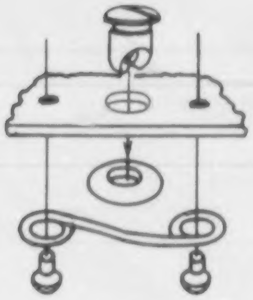
Quick Locking Devices



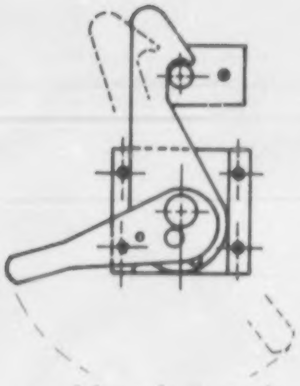
Link Lock



Hinge Lock

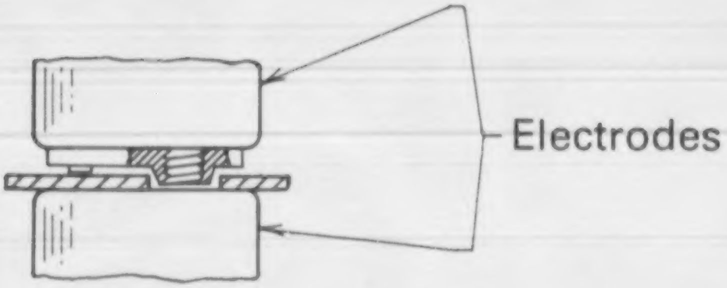


Quarter Turn

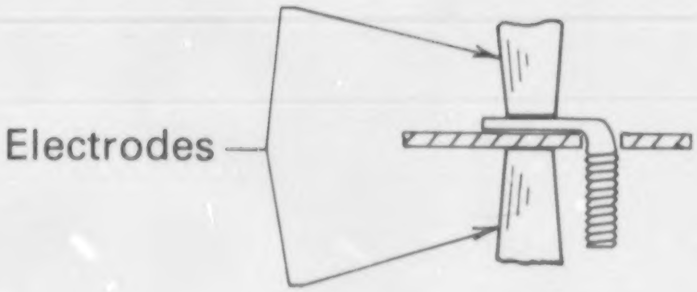


Hook Lock

Attaching Resistance Weld Fasteners


Electrodes

Projection
Welded

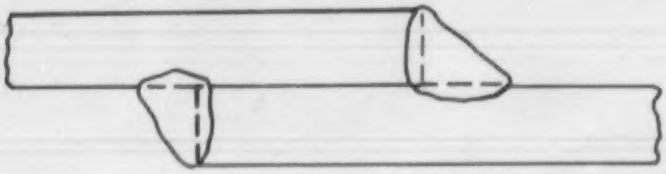

Electrodes

Spot Welded

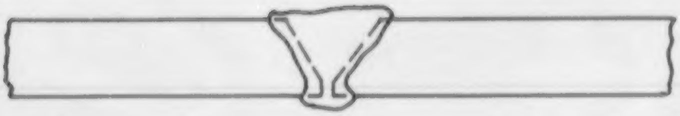
Welding Advantages

1. Is Fast and Relatively Simple
2. Saves Time and Expense
3. Causes Less Weight Than Casting or Forging the Part in Most Cases
4. Has a Neater Appearance
5. Is Less Noisy
6. Simplifies Painting Process
7. Is Good for Small Quantity Jobs

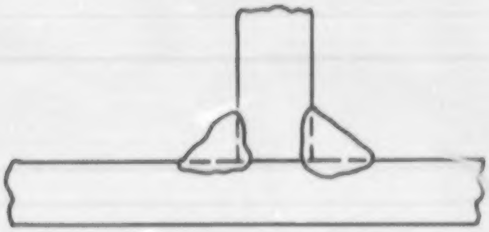
Types of Welded Joints



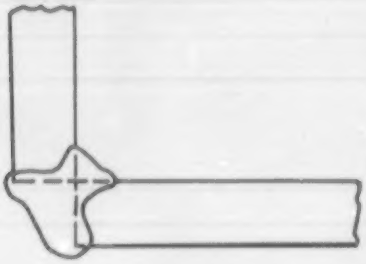
Lap Joint



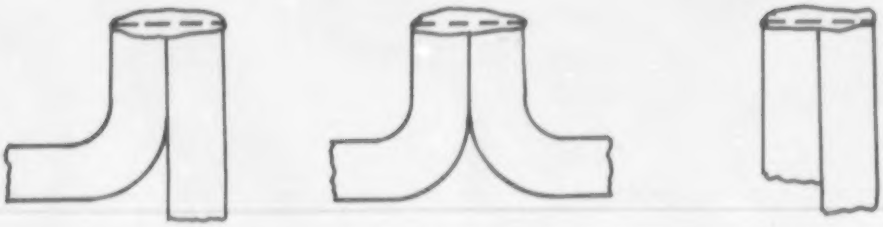
Butt Joint



Tee Joint

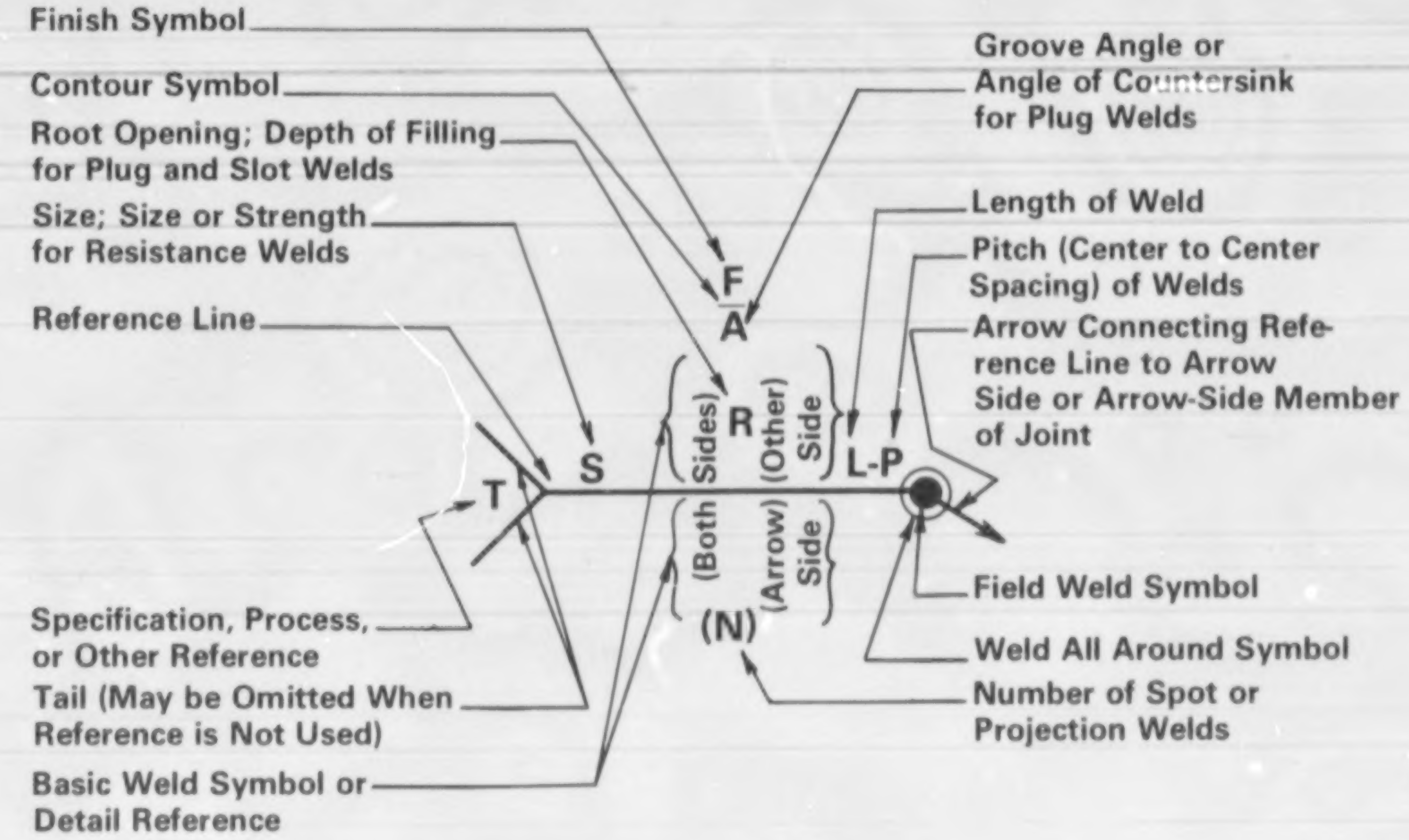


Corner Joint

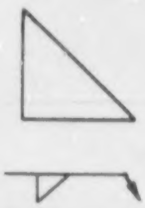
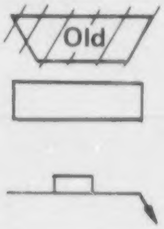
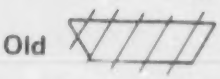


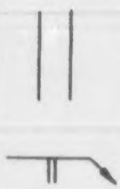
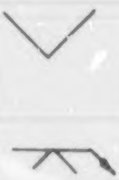
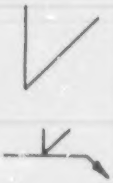
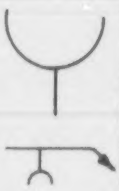
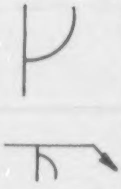
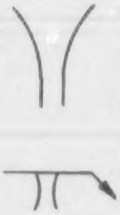
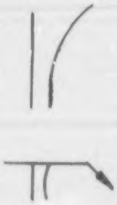
Edge Joints

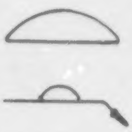
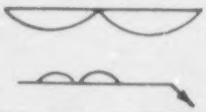
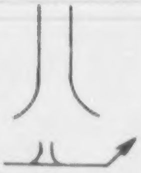
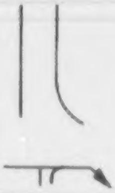
Parts of a Welding Symbol


Finish Symbol
Contour Symbol
Root Opening; Depth of Filling for Plug and Slot Welds
Size; Size or Strength for Resistance Welds
Reference Line
Specification, Process, or Other Reference
Tail (May be Omitted When Reference is Not Used)
Basic Weld Symbol or Detail Reference
Groove Angle or Angle of Countersink for Plug Welds
Length of Weld
Pitch (Center to Center Spacing) of Welds
Arrow Connecting Reference Line to Arrow Side or Arrow-Side Member of Joint
Field Weld Symbol
Weld All Around Symbol
Number of Spot or Projection Welds
F
A
R
S
T
L-P
(N)
(Both Sides)
(Other) Side
(Arrow) Side

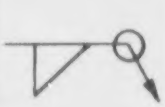
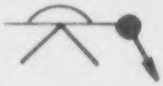
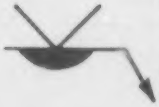
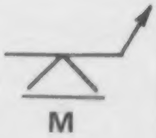
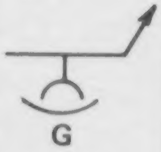
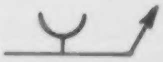
Basic Arc and Gas Welding Symbols

Fillet	Plug or Slot	Arc - Spot or Arc - Seam
		

Groove						
Square	V	Bevel	U	J	Flare V	Flare Bevel
						

Back or Backing	Surfacing	Flange	
		Edge	Corner
			

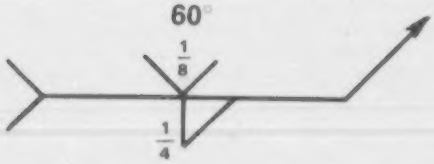
Supplementary Symbols

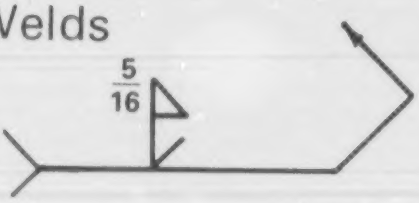
Weld All Around	Field Weld	Melt Thru	Contour		
			Flush	Convex	Concave
○	●	◒	—	⌒	◡
					

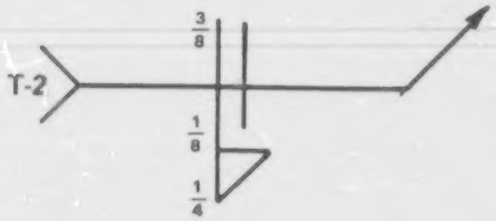
M – Machine
G – Grind

Supplementary Symbols

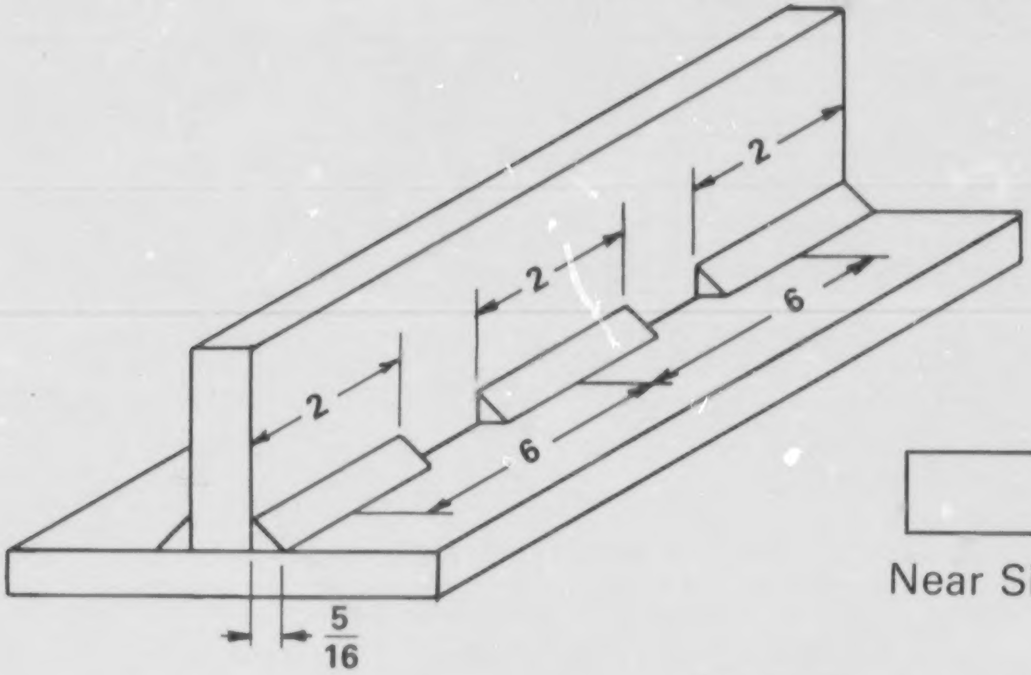
Combined Welds

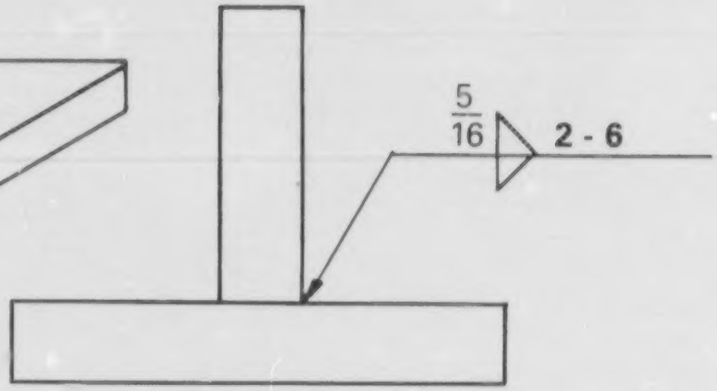




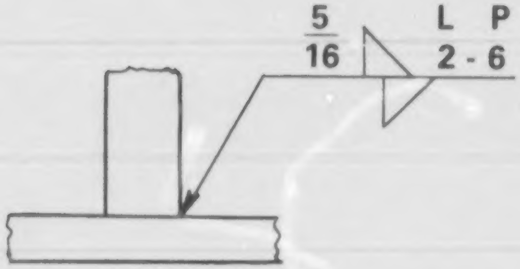


Dimensioning of Welds

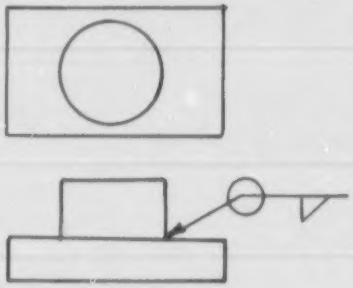




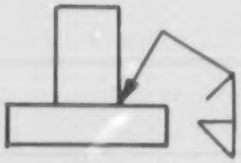
Near Side - Opposite Side



Staggered



Weld All Around



Combination Weld

Resistance Welding Symbols

<table>
<tr><th colspan="4">Type of Weld</th></tr>
<tr><th>Resistance Spot</th><th>Projection</th><th>Resistance Seam</th><th>Flash or Upset</th></tr>
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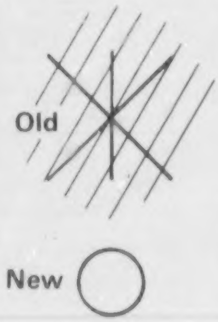
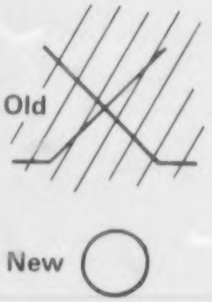
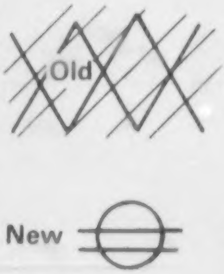
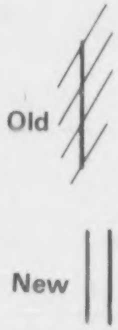
<td> </td>
<td> </td>
<td> </td>
<td> </td>
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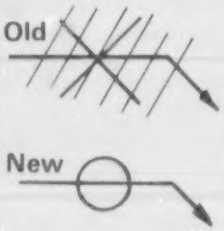
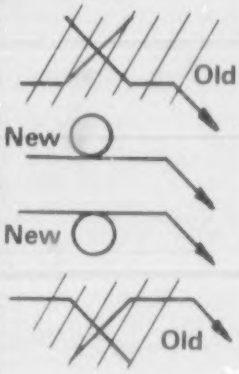
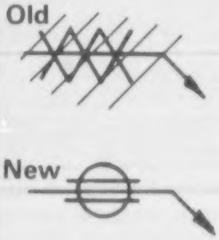
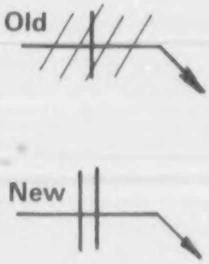
<td> </td>
<td>

Old
New
New
Old

</td>
<td> </td>
<td> </td>
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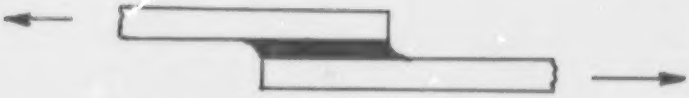
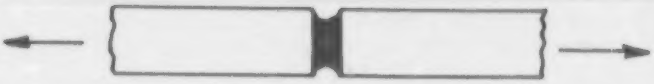
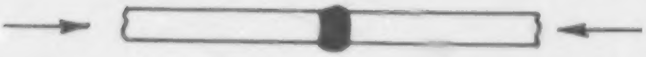
Stresses on Bonded Joints



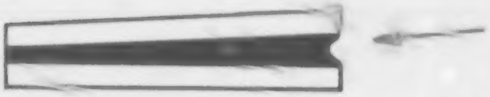
Shear



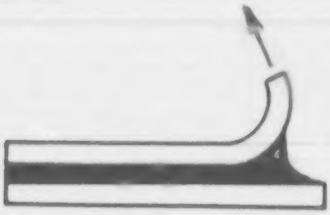
Tension



Compression

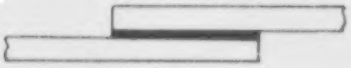


Cleavage

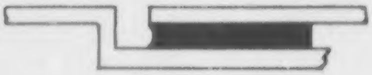


Peel

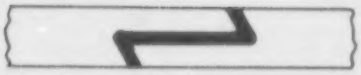
Joint Design for Adhesive Bonding



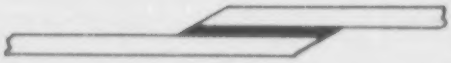
Lap Joint



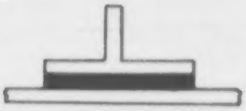
Joggle Lap



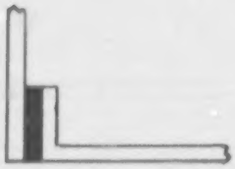
Double Butt Lap



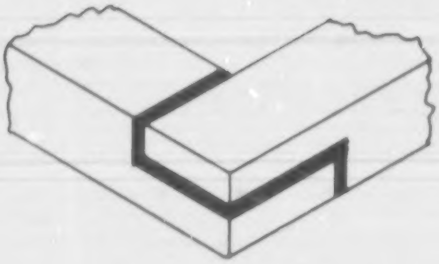
Tapered Lap



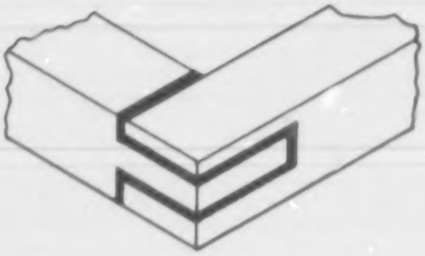
T Section
Stiffener



Corner Joint



End Lap Joint



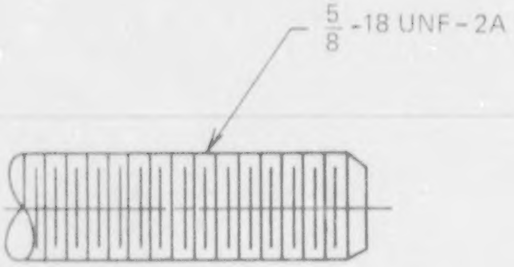
Mortise and
Tenon

FASTENERS AND HARDWARE
UNIT VI

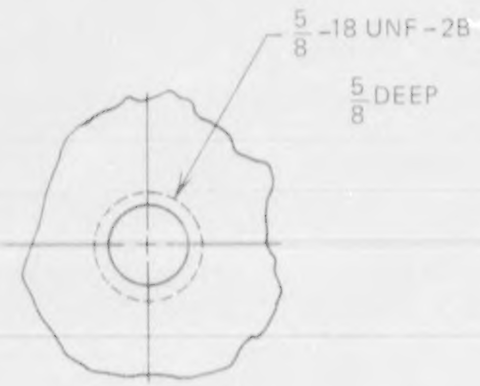
ASSIGNMENT SHEET #1–CONSTRUCT THREAD SYMBOLS

Directions: Using the screw thread tables included with this assignment sheet, draw on "B" size vellum or other media to a full or proper scale the thread symbols indicated in the problems. Use the correct type of symbol, and letter the correct thread note as shown in the following example.

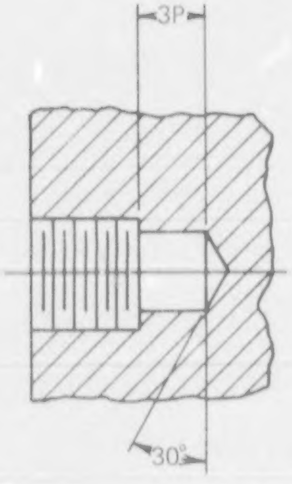
Example:


$\frac{5}{8}$-18 UNF-2A

Schematic


$\frac{5}{8}$-18 UNF-2B
$\frac{5}{8}$ DEEP

Circular View



Section

ASSIGNMENT SHEET #1

Problems:

A. Simplified external thread M 10 x 1.5 - 6gA

B. Simplified internal thread M 10 x 1.5 - 6HB thru 3/4 - 10NC - 2LH - 1.00 deep

C. Simplified external thread 3/4-10NC - 2LH

D. Simplified internal thread 3/4-10NC-2LH-1.00 deep

E. Schematic external thread M3 x .5C-A

F. Schematic internal thread M3 x .5C-B

G. Schematic external thread 1/4 - 20 UNC-2A

H. Schematic internal thread 1/4 -20 UNC-2B thru

TABLE 1-A

AMERICAN NATIONAL STANDARD UNIFIED AND AMERICAN NATIONAL SCREW THREADS[1]

Nominal Diameter	Coarse[2] NC UNC		Fine[2] NF UNF		Extra Fine[3] NEF UNEF	
	Thds. per Inch	Tap Drill[5]	Thds. per Inch	Tap Drill[5]	Thds. per Inch	Tap Drill[5]
0 (.060)			80	3/64		
1 (.073)	64	No. 53	72	No. 53		
2 (.086)	56	No. 50	64	No. 50		
3 (.099)	48	No. 47	56	No. 45		
4 (.112)	40	No. 43	48	No. 42		
5 (.125)	40	No. 38	44	No. 37		
6 (.138)	32	No. 36	40	No. 33		
8 (.164)	32	No. 29	36	No. 29		
10 (.190)	24	No. 25	32	No. 21		
12 (.216)	24	No. 16	28	No. 14	32	No. 13
1/4	20	No. 7	28	No. 3	32	7/32
5/16	18	F	24	I	32	9/32
3/8	16	5/16	24	Q	32	11/32
7/16	14	U	20	25/64	28	13/32
1/2	13	27/64	20	29/64	28	15/32
9/16	12	31/64	18	33/64	24	33/64
5/8	11	17/32	18	37/64	24	37/64
11/16					24	41/64
3/4	10	21/32	16	11/16	20	45/64
13/16					20	49/64
7/8	9	49/64	14	13/16	20	53/64
15/16					20	57/64
1	8	7/8	12	59/64	20	61/64
1 1/16					18	1
1 1/8	7	63/64	12	1 3/64	18	1 5/64
1 3/16					18	1 9/64
1 1/4	7	1 7/64	12	1 11/64	18	1 3/16
1 5/16					18	1 17/64
1 3/8	6	1 7/32	12	1 19/64	18	1 5/16
1 7/16					18	1 3/8
1 1/2	6	1 11/32	12	1 27/64	18	1 7/16
1 9/16					18	1 1/2
1 5/8					18	1 9/16
1 11/16					18	1 5/8
1 3/4	5	1 9/16				
2	4 1/2	1 25/32				
2 1/4	4 1/2	2 1/32				
2 1/2	4	2 1/4				
2 3/4	4	2 1/2				
3	4	2 3/4				
3 1/4	4					
3 1/2	4					
3 3/4	4					
4	4					

Nominal Diameter	8 Pitch[3] Series 8N and 8UN		12 Pitch[3] Series 12N and 12UN		16 Pitch[3] Series 16N and 16UN	
	Thds. per Inch	Tap Drill[5]	Thds. per Inch	Tap Drill[5]	Thds. per Inch	Tap Drill[5]
1/2			12	27/64		
9/16			12	31/64		
5/8			12	35/64		
11/16			12	39/64		
3/4			12	43/64	16	11/16
13/16			12	47/64	16	3/4
7/8			12	51/64	16	13/16
5/16			12	55/64	16	7/8
1	8	7/8	12	59/64	16	15/16
1 1/16			12	63/64	16	1
1 1/8	8	1	12	1 3/64	16	1 1/16
1 3/16			12	1 7/64	16	1 1/8
1 1/4	8	1 1/8	12	1 11/64	16	1 3/16
1 5/16			12	1 15/64	16	1 1/4
1 3/8	8	1 1/4	12	1 19/64	16	1 5/16
1 7/16			12	1 23/64	16	1 3/8
1 1/2	8	1 3/8	12	1 27/64	16	1 7/16
1 9/16					16	1 1/2
1 5/8	8	1 1/2	12	1 35/64	16	1 9/16
1 11/16					16	1 5/8
1 3/4	8	1 5/8	12	1 43/64	16	1 11/16
1 13/16					16	1 3/4
1 7/8	8	1 3/4	12	1 51/64	16	1 13/16
1 15/16					16	1 7/8
2	8	1 7/8	12	1 59/64	16	1 15/16
2 1/16					16	2
2 1/8			12	2 3/64	16	2 1/16
2 3/16					16	2 1/8
2 1/4	8	2 1/8	12	2 11/64	16	2 3/16
2 5/16					16	2 1/4
2 3/8			12	2 19/64	16	2 5/16
2 7/16					16	2 3/8
2 1/2	8	2 3/8	12	2 27/64	16	2 7/16
2 5/8			12	2 35/64	16	2 9/16
2 3/4	8	2 5/8	12	2 43/64	16	2 11/16
2 7/8			12		16	
3	8	2 7/8	12		16	
3 1/8			12		16	
3 1/4	8		12		16	
3 3/8			12		16	
3 1/2	8		12		16	
3 5/8			12		16	
3 3/4	8		12		16	
3 7/8			12		16	
4	8		12		16	
4 1/4	8		12		16	
4 1/2	8		12		16	
4 3/4	8		12		16	
5	8		12		16	
5 1/4	8		12		16	

[1] ANSI B1.1

[2] Classes 1A, 2A, 3A, 1B, 2B, 3B, 2 and 3

[3] Classes 2A, 3A, 2B, 3B, 2 and 3

[4] Classes 2A, 2B, 2 and 3

[5] For approximate 75% full depth of thread

TABLE 1-8

METRIC SCREW THREADS

Coarse general purpose		Fine	
Nominal Size & Thd Pitch	Tap Drill Diameter, mm	Nominal Size & Thd Pitch	Tap Drill Diameter, mm
M1.6 X 0.35	1.25	....	....
M1.8 X 0.35	1.45	....	....
*M2 X 0.4	1.6	....	....
M2.2 X 0.45	1.75	....	....
*M2.5 X 0.45	2.05	....	....
*M3 X 0.5	2.50	....	....
*M3.5 X 0.6	2.90	....	....
*M4 X 0.7	3.30	....	....
M4.5 X 0.75	3.75	....	....
*M5 X 0.8	4.20	....	....
*M6.3 X 1	5.30	....	....
M7 X 1	6.00	....	....
*M8 X 1.25	6.80	*M8 X 1	7.00
M9 X 1.25	7.75	....	....
*M10 X 1.5	8.50	*M10 X 1.25	8.75
M11 X 1.5	9.50	....	....
*M12 X 1.75	10.30	*M12 X 1.25	10.50
*M14 X 2	12.00	*M14 X 1.5	12.50
*M16 X 2	14.00	*M16 X 1.5	14.50
M18 X 2.5	15.50	M18 X 1.5	16.50
*M20 X 2.5	17.50	*M20 X 1.5	18.50
M22 X 2.5	19.50	M22 X 1.5	20.50
*M24 X 3	21.00	*M24 X 2	22.00
M27 X 3	24.00	M27 X 2	25.00
*M30 X 3.5	26.50	*M30 X2	28.00
M33 X 3.5	29.50	M30 X 2	31.00
*M36 X 4	32.00	*M36 X 3	33.00
M39 X 4	35.00	M39 X 3	36.00
*M42 X 4.5	37.50	*M42 X 3	39.00
M45 X 4.5	40.50	M45 X 3	42.00
*M48 X 5	43.00	*M48 X 3	45.00
M52 X 5	47.00	M52 X 3	49.00
*M56 X 5.5	50.50	*M56 X 4	52.00
M60 X 5.5	54.50	M60 X 4	56.00
*M64 X 6	58.00	*M64 X 4	60.00
M68 X 6	62.00	M68 X 4	64.00
*M72 X 6	66.00	....	....
*M80 X 6	74.00	....	....
*M90 X 6	84.00	....	....
*M100 X 6	94.00	....	....

Metric Fasteners Standards IFI 500 (1976)

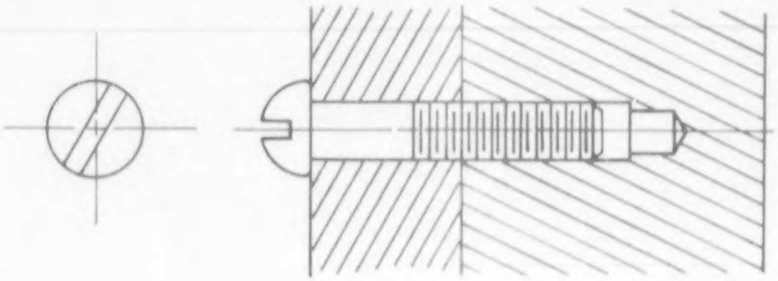
*Preferred sizes for commercial threads and fasteners

FASTENERS AND HARDWARE
UNIT VI

ASSIGNMENT SHEET #2--CONSTRUCT BOLTS, SCREWS, AND NUTS

Directions: Using bolt, screw, and nut tables, draw on "B" size vellum or other media to a full or proper scale the fasteners indicated in the problems. Each fastener is to be drawn holding parts together. Letter correct description abbreviated below each symbol as shown in the following example.

Example:



ASSIGNMENT SHEET #2

Problems:

(NOTE: All tap drill sizes should be specified for external.)

A. M6.3 x 1 - 40 mm long hexagon head cap screw

B. 3/4 x 2 1/2 hexagon head cap screw

C. 5/8 - 11 unc - 2B square nut

D. M 6.3 x 1 hexagon nut

E. 3/4 - 10UNC - 2A 2 1/2 long hexagon cap screw

F. No. 10 (.1900) - 32NF - 3, 5/8 long fillister head machine screw

G. M8 x 1.25, 30mm long slotted pan head machine screws

H. 3/8 - 16 UNC - 2A, 3/4 long square head flat point set screw

I. M10 x 1.5 12mm long hexagon socket head set screw full dog point

J. #204 woodruff key

FASTENERS AND HARDWARE
UNIT VI

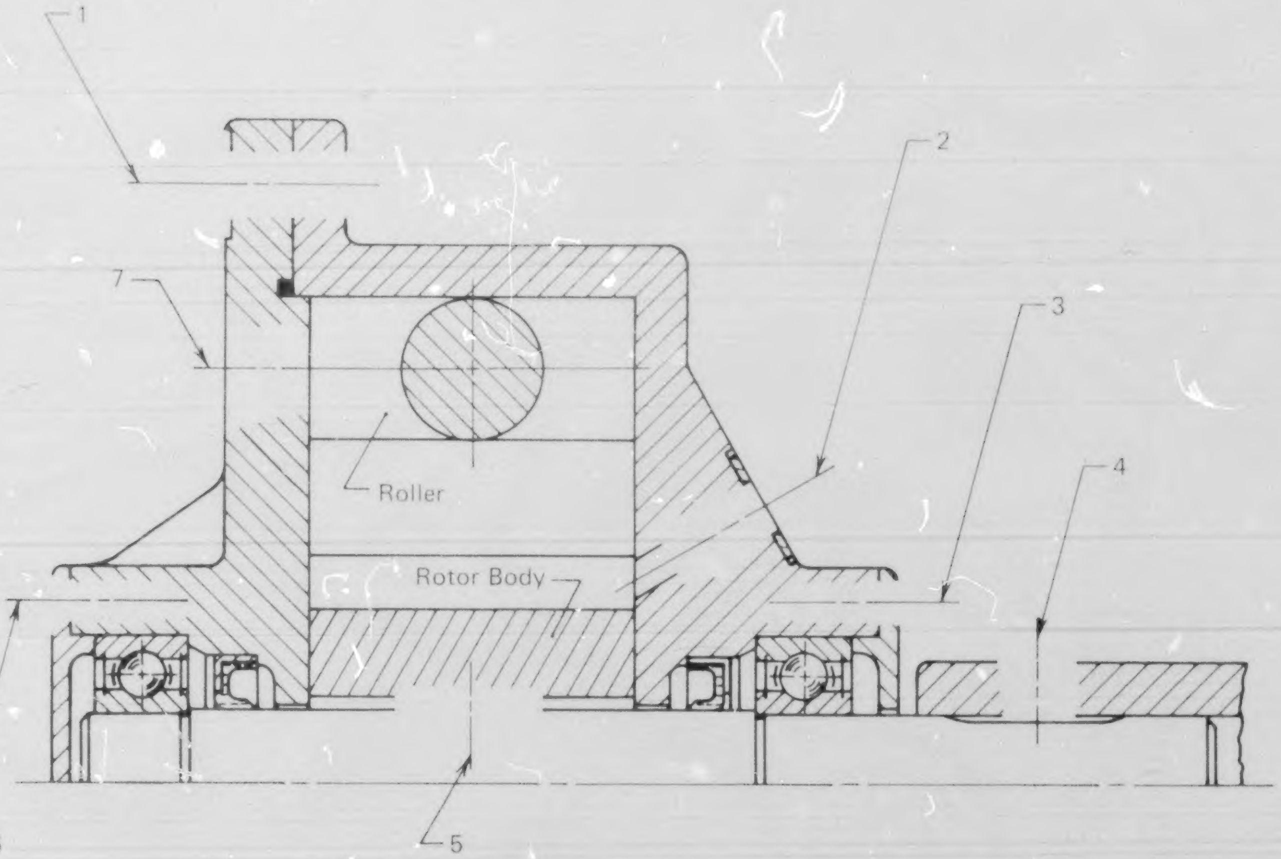
ASSIGNMENT SHEET #3–CONSTRUCT AN ASSEMBLY CONTAINING VARIOUS FASTENERS

Directions: Using fastener tables, draw on "B" size vellum or other media an assembly drawing with the following fasteners:

1. 3/8 x 1" hexagon cap screw and American Standard regular lockwasher
2. 3/8 x 1/2 slotted pan head machine screw and special washer
3. No. 10 x 1/2 slotted round head machine screw
4. 3/8 x 1/2 slotted headless cup point set screw
5. #606 Woodruff key
6. #10 x 1/2 slotted oval head machine screw
7. 3/4 pipe tap

Letter correct fastener descriptions in parts list directly above title block. Complete the sectioned assembly as specified by instructor.

ASSIGNMENT SHEET #3


1
2
3
4
7
Roller
Rotor Body
6
5

HYDRAULIC PUMP

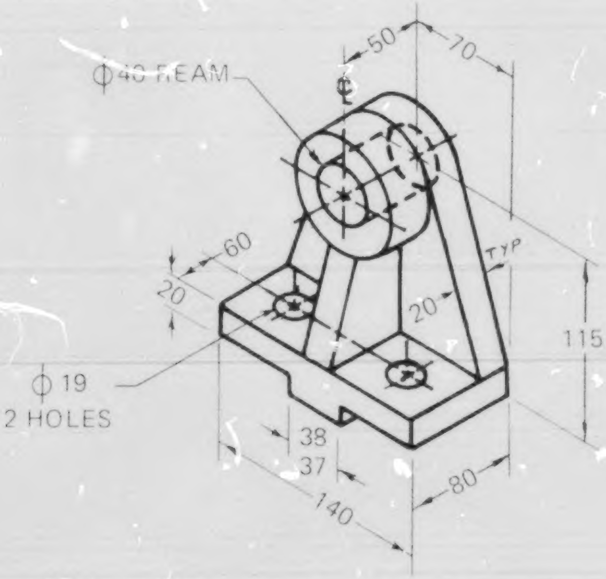
FASTENERS AND HARDWARE
UNIT VI

ASSIGNMENT SHEET #4–CONSTRUCT A WELDED ASSEMBLY DRAWING

Directions: Select problem A or B and make into a welded drawing on a "B" size sheet of vellum or other media. Use proper welding symbols as shown in a welding symbol chart, and completely dimension.

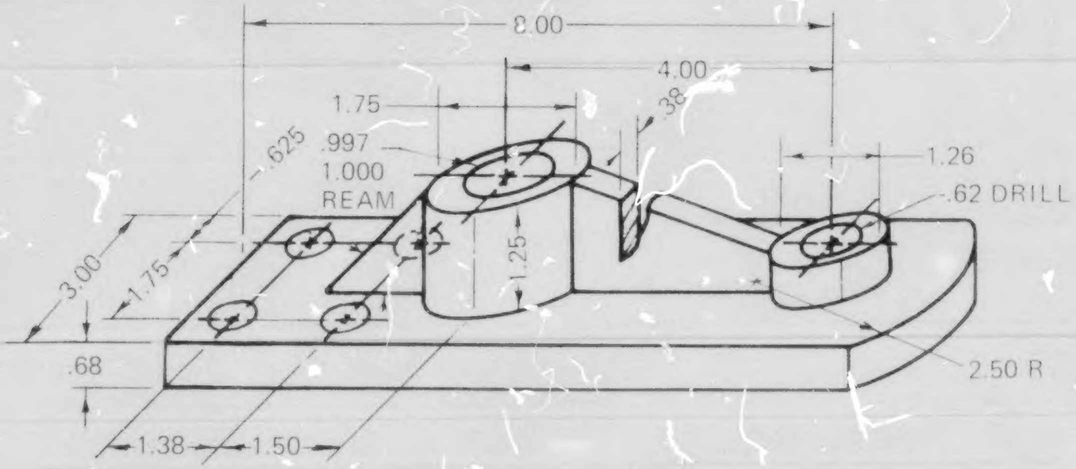
Problems:

A. Bracket–Metric
Scale 1:10



Φ40 REAM
℄
50
70
60
20
TYP
20
115
Φ19
2 HOLES
38
37
140
80

B. Stop base–inch
Scale 1/4"=1"



8.00
4.00
1.75
.38
.625
.997
1.000
REAM
1.26
.62 DRILL
1.25
3.00
1.75
.68
1.38
1.50
2.50 R

FASTENERS AND HARDWARE
UNIT VI

ASSIGNMENT SHEET #5–CONSTRUCT SPRING DRAWINGS TO INCLUDE SPECIFICATIONS

Directions: On "A" size vellum or other media, construct spring drawings to include the specifications listed for each problem.

Problems:

A. Detail drawing representation of a compressed spring with the following specifications:

   1. 2" free length
   2. 10 gage diameter of wire
   3. 3/4" OD
   4. 1/4 pitch

B. Schematic drawing of an extension spring with the following specifications:

   1. 3" length
   2. 2 1/2" free length
   3. 5/8" OD
   4. 1/4 pitch

C. Schematic drawing of a torsion spring with the following specifications:

   1. 4" length
   2. 15 coils
   3. 1/8" OD
   4. Length of ends 1 1/4"
   5. Angle 50°

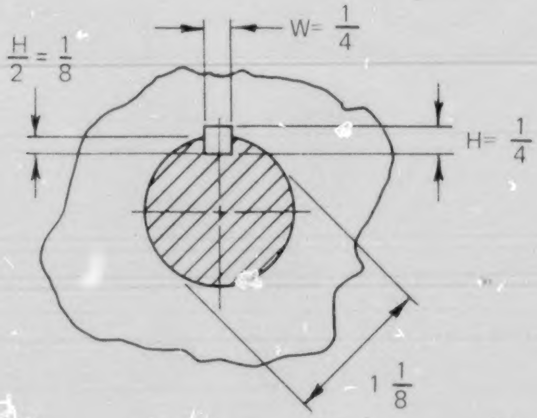
FASTENERS AND HARDWARE
UNIT VI

ASSIGNMENT SHEET #6--CONSTRUCT KEYS IN ASSEMBLED POSITIONS

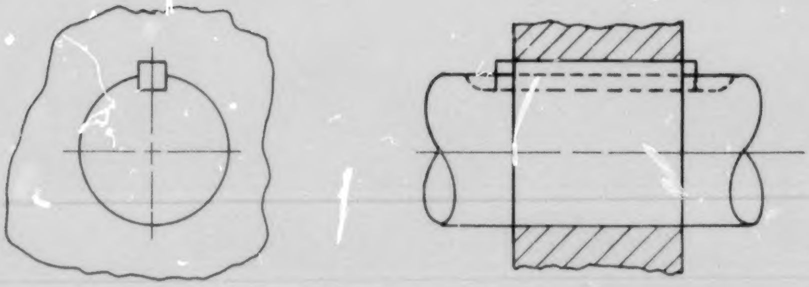
Directions: Using the tables included with this assignment sheet, construct keys for the problems given by using the procedure in the following example.

Example: Construct an assembled detailed drawing of a 1 1/8" shaft square keyed to a wheel. Only show detail of the key, shaft, and wheel.

1. Using Table 6-C, find shaft diameter range for 1 1/8" shaft
2. Answer is 15/16" to 1 1/4"
3. Reading across the line, square stock key says W = 1/4 and H = 1/4
4. Draw detail based on dimensions in illustration



DRAWING INFORMATION



DRAWING

ASSIGNMENT SHEET #6

Problems:

A: Construct an assembled detailed drawing of a 1 1/2" diameter shaft square keyed to a wheel. Only show detail of the key, shaft, and wheel. Draw in 1/2" = 1" scale in the upper left quarter of the "A" size vellum. Letter title and scale under detail.

B: Construct an assembled detailed drawing of a 4 3/4" diameter shaft flat keyed to a wheel. Only show detail of the key, shaft, and wheel. Draw in 1/4" = 1' scale in the upper right quarter of the "A" size vellum. Letter title and scale under detail.

C: Construct an assembled detailed drawing of a 9/16" diameter shaft Woodruff keyed to a pulley. Only show detail of the key, shaft, and pulley. Draw in 2 X scale in the lower left quarter of the "A" size vellum. Letter title and scale under detail.

(NOTE: Table 6-A will locate the Woodruff key size and Table 6-B will give the drawing details.)

D: Construct an assembled detailed drawing of a 1 3/4" diameter shaft Woodruff keyed to a hub. Only show detail of the key, hub, and shaft. Draw in full size in the lower right quarter of the "A" size vellum. Letter title and scale under detail.

TABLE 6-A

Woodruff Keys[1] - American National Standard

Key No.[2]	Nominal Sizes				Maximum Sizes		
	A X B	E	F	G	H	D	C
204	1/16 X 1/2	3/64	1/32	5/64	.194	.1718	.203
304	3/32 X 1/2	3/64	3/64	3/32	.194	.1561	.203
305	3/32 X 5/8	1/16	3/64	7/64	.240	.2031	.250
404	1/8 X 1/2	3/64	1/16	7/64	.194	.1405	.203
405	1/8 X 5/8	1/16	1/16	1/8	.240	.1875	.250
406	1/8 X 3/4	1/16	1/16	1/8	.303	.2505	.313
505	5/32 X 5/8	1/16	5/64	9/64	.240	.1719	.250
506	5/32 X 3/4	1/16	5/64	9/64	.303	.2349	.313
507	5/32 X 7/8	1/16	5/64	9/64	.365	.2969	.375
606	3/16 X 3/4	1/16	3/32	5/32	.303	.2193	.313
607	3/16 X 7/8	1/16	3/32	5/32	.365	.2813	.375
608	3/16 X 1	1/16	3/32	5/32	.428	.3443	.438
609	3/16 X 1 1/8	5/64	3/32	11/64	.475	.3903	.484
807	1/4 X 7/8	1/16	1/8	3/16	.365	.2500	.375
808	1/4 X 1	1/16	1/8	3/16	.428	.3130	.438
809	1/4 X 1 1/8	5/64	1/8	13/64	.475	.3590	.484
810	1/10 X 1 1/4	5/64	1/8	13/64	.537	.4220	.547
811	1/4 X 1 3/8	3/32	1/8	7/32	.584	.4690	.594
812	1/4 X 1 1/2	7/64	1/8	15/64	.631	.5160	.641
1008	5/16 X 1	1/16	5/32	7/32	.428	.2818	.438
1009	5/16 X 1 1/8	5/64	5/32	15/64	.475	.3278	.484
1010	5/16 X 1 1/4	5/64	5/32	15/64	.537	.3908	.547
1011	5/16 X 1 3/8	3/32	5/32	8/32	.584	.4378	.594
1012	5/16 X 1 1/2	7/64	5/32	17/64	.631	.4848	.641
1210	3/8 X 1 1/4	8/64	3/16	17/64	.537	.3595	.547
1211	3/8 X 1 3/8	3/32	3/16	9/32	.584	.4065	.594
1212	3/8 X 1 1/2	7/64	3/16	19/64	.631	.4335	.641

[1] ANSI B17.2-1967, R1972

[2] Key numbers indicate nominal key dimensions. The last two digits give the nominal diameter B in eights of an inch, and the digits before the last two give the nominal width A in thirty-seconds of an inch.

TABLE 6-B

Woodruff Key Sizes for Different Shaft Diameters[1]

Shaft Diameter	5/16 to 3/8	7/16 to 1/2	9/16 to 3/4	13/16 to 15/16	1 to 1 3/16	1 1/4 to 1 7/16	1 1/2 to 1 3/4	1 13/16 to 2 1/8	2 3/16 to 2 1/2
Key Numbers	204	304 305	404 405 406	505 506 507	606 607 608 609	807 808 809	810 811 812	1011 1012	1211 1212

[1] Suggested sizes; not standard.

TABLE 6-C

Keys–Square, Flat, Plain Taper[1], and Gib Head

Shaft Diameters	Square Stock Key	Flat Stock Key	Gib Head Taper Stock Key					
			Square			Flat		
			Height	Length	Height to Chamfer	Height	Length	Height to Chamfer
D	W = H	W X H	C	F	E	C	F	E
1/2 to 9/16	1/8	1/8 X 3/32	1/4	7/32	5/32	3/16	1/8	1/8
5/8 to 7/8	3/16	3/16 X 1/8	5/16	9/32	7/32	1/4	3/16	5/32
15/16 to 1 1/4	1/4	1/4 X 3/16	7/16	11/32	11/32	5/16	1/4	3/16
1 5/16 to 1 3/8	5/16	5/16 X 1/4	9/16	13/32	13/32	3/8	5/16	1/4
1 7/16 to 1 3/4	3/8	3/8 X 1/4	11/16	15/32	15/32	7/16	3/8	5/16
1 13/16 to 2 1/4	1/2	1/2 X 3/8	7/8	19/32	5/8	5/8	1/2	7/16
2 5/16 to 2 3/4	5/8	5/8 X 7/16	1 1/16	23/32	3/4	3/4	5/8	1/2
2 7/8 to 3 1/4	3/4	3/4 X 1/2	1 1/4	7/8	7/8	7/8	3/4	5/8
3 3/8 to 3 3/4	7/8	7/8 X 5/8	1 1/2	1	1	1 1/16	7/8	3/4
3 7/8 to 4 1/2	1	1 X 3/4	1 3/4	1 3/16	1 3/16	1 1/4	1	13/16
4 3/4 to 5 1/2	1 1/4	1 1/4 X 7/8	2	1 7/16	7/16	1 1/2	1 1/4	1
5 3/4 to 6	1 1/2	1 1/2 X 1	2 1/2	1 3/4	1 3/4	1 3/4	1 1/2	1 1/4

[1] Plain taper square and flat keys have the same dimensions as the plain parallel stock keys, with the addition of the taper on top. Gib head taper square and flat keys have the same dimensions as the plain taper keys, with the addition of the gib head.

Stock lengths for plain taper and gib head taper keys: The minimum stock length equals 4W, and the maximum equals 16W. The increments of increase of length equal 2W.

FASTENERS AND HARDWARE
UNIT VI

ASSIGNMENT SHEET #7--WRITE SPECIFICATIONS FOR HARDWARE FROM VENDER CATALOGS

Directions: Find the hardware items for each problem in vender catalogs of hardware such as the *Thomas Register*. Select a specific size or type for each problem. Write a specification to include vender's name and address, cost, material, and specific specification (size, length, type, etc.) of each hardware item selected. Letter answer on "A" size vellum converting sheet to a parts list to include part number, description (vender's name, address, and specification), cost, and material.

Problems:

A. Compression spring

B. Tension spring

C. Woodruff key

D. Internal tooth washer

E. Dart-type spring clip

F. Spring washer to control end pressure

G. Hook lock fastener--quick operating

H. Weld nut

FASTENERS AND HARDWARE
UNIT VI

NAME ______________________________

TEST

1. Match the terms on the right with the correct definitions.

______a. Head having a slot centered across the top

______b. Fastener having high tensile and shear strength

______c. Thread on the inside of a hole

______d. Thread having one start, and the lead is equal to the pitch

______e. Least amount of drawing information necessary to convey information without confusion

______f. Chemical bonding between parts

______g. Mechanical device for holding two or more parts in a set position

______h. Fastener with wide tolerances and all surfaces in their formed conditions

______i. Head having a specially formed indentation centered in its top

______j. Fastener made to close tolerance having a high grade finish

______k. Advances when turned clockwise

______l. Distance a screw travels in one rotation

______m. Close approximation to actual appearance

______n. More detailed than simplified but faster to draw than detailed threads

______o. Fastener made with greater tolerances than a finished fastener and having only the bearing surface and threads finished

______p. Profile of the thread

1. Fastener
2. Keys
3. Finished fastener
4. High strength fastener
5. Semi-finished fastener
6. Hardware
7. Unfinished fastener
8. Slotted head
9. Recessed head
10. Nuts
11. Screw thread form
12. Schematic threads
13. Simplified threads
14. Detailed threads
15. O-Rings
16. External thread
17. Internal thread
18. Retaining ring
19. Lead
20. Series of thread
21. Single thread
22. Multiple threads
23. Pins
24. Springs

______q. Thread on the outside of a shaft

______r. Number of threads per inch based on standard nominal diameters

______s. Thread having multiple starts, and the lead is equal to a multiple of the pitch

______t. Joining parts by melting base metal to form a unit structure to support loads

______u. Advances when turned counterclockwise

______v. Small parts such as fasteners, springs, and washers

______w. Used for storage of mechanical energy

______x. Used to attach wheels, pulleys, and gears to shafts

______y. Designed to insulate, lubricate, span large holes, and distribute stress over a larger area

______z. Designed for fastening, adjusting, and transmitting motion or power

______aa. Designed for semi-permanent attachment or location

______bb. Used to seal along a shaft

______cc. Has a removable shoulder to accurately retain, locate, or lock components in bases and housings or on shafts

25. Right hand thread
26. Left hand thread
27. Welding
28. Washers
29. Adhesive

2. Name two general types of fasteners.

a. ______________________________

b. ______________________________

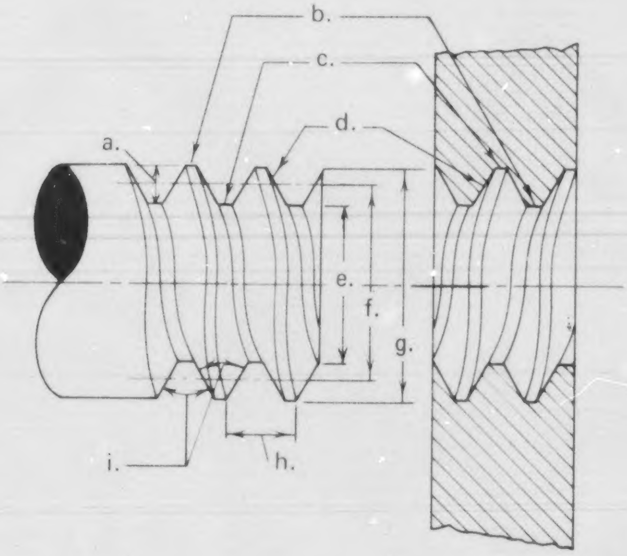
3. Name three basic applications of screw threads.

a. ______________________________

b. ______________________________

c. ______________________________

4. Identify screw thread nomenclature.

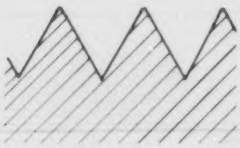
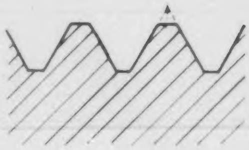
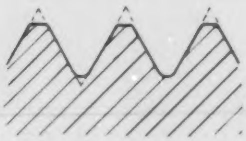


a. ______________ b. ______________ c. ______________

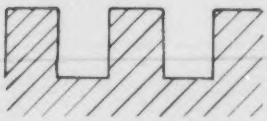
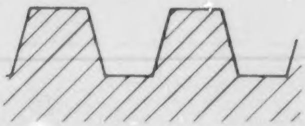
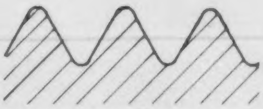
d. ______________ e. ______________ f. ______________

g. ______________ h. ______________ i. ______________

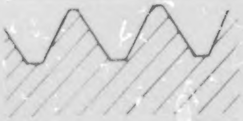
5. Identify screw thread profiles.

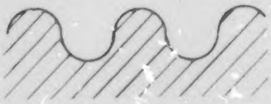
a. ______________ b. ______________ c. ______________

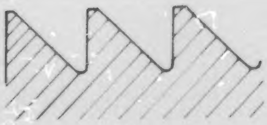
d. ______________ e. ______________ f. ______________



g. ____________________



h. ____________________



i. ____________________

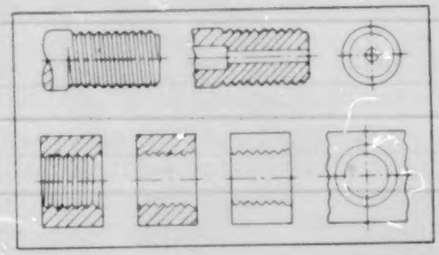
6. Compute lead of thread for the following problems.

a. Single thread, 10 threads per inch L = ____________

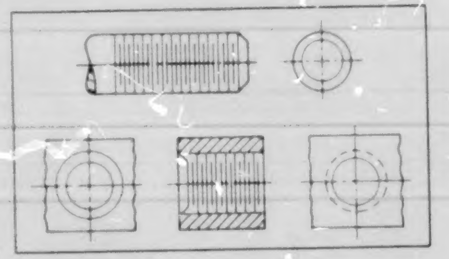
b. Double thread, 18 threads per inch L = ____________

c. Triple thread, 24 threads per inch L = ____________

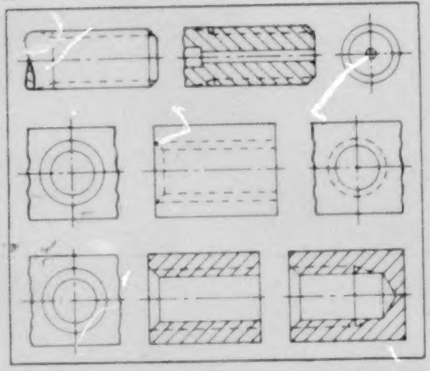
7. Identify screw thread symbols.



a. ____________________________



b. ____________________________



c. ____________________________

8. Match classes of fit for unified threads on the right with the correct uses.

______a. For general purposes and most common uses

______b. For close tolerance screw thread

______c. For parts that are easy to assemble; ordinance and other special uses; quick assembly

1. Classes 1A and 1B
2. Classes 2A and 2B
3. Classes 3A and 3B

9. List two classes of fit for metric threads.

a. ______________________________

b. ______________________________

10. Identify parts of thread notes.

a. b. c. d. e.

$\frac{7}{8}$ – 9 NC–2 LH–1.00 DEEP

f. g. h. i. j.

M 6.3 X 1 6H B LH

a. ______________________ b. ______________________

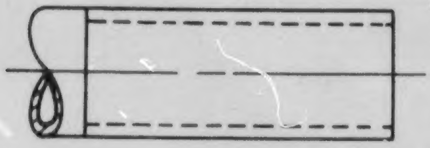
c. ______________________ d. ______________________

e. ______________________ f. ______________________

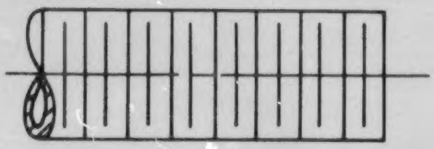
g. ______________________ h. ______________________

i ______________________ j. ______________________

11. Distinguish between conventional representations of pipe threads by placing an "X" next to the thread drawn in schematic and an "O" next to the thread drawn in simplified.



______a.



______b.

12. List four types of threaded removable fasteners.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

13. Name two shapes of bolts and nuts.

a. ______________________________

b. ______________________________

14. Select types of locknuts and locking devices by placing an "X" in the appropriate blanks.

______a. Fillister head

______b. Cotter pin

______c. Set screw

______d. Fluted socket

______e. Welding

______f. Hex slotted nut

15. Name four types of standard cap screws.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

16. Complete the following list of types of machine screws.

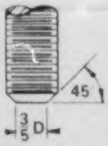
a. Round head

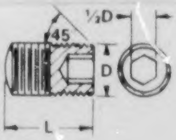
b. ______________________________

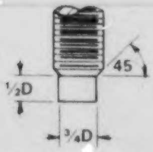
c. Oval head

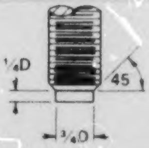
d. Fillister head

17. Identify set screw heads and points.



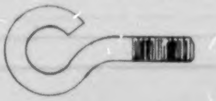


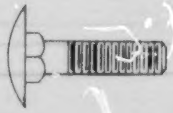




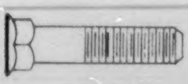
a. ____________ b. ____________ c. ____________ d. ____________

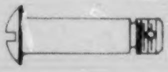
18. Identify miscellaneous bolts and screws.



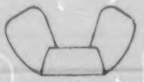


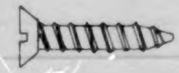
a. ________________________________ b. ________________________________





c. ________________________________ d. ________________________________

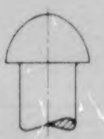


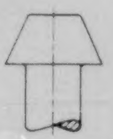


e. ________________________________ f. ________________________________

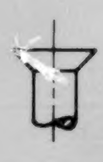
19. Identify standard large and small rivets.

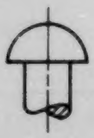
Large rivets





Small rivets





a. ____________ b. ____________ c. ____________ d. ____________

20. Match conventional rivet symbols on the right with the correct identifications.

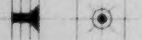
______a. Field rivet--Two full heads

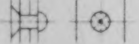
______b. Shop rivet--Countersunk and chipped; far side

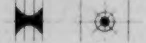
______c. Shop rivet--Flattened to 1/4", 1/2" and 5/8" rivets; far side

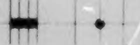
______d. Field rivet--Countersunk; near side

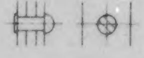
______e. Field rivet--Countersunk; both sides

1. 

2. 

3. 

4. 

5. 

21. List three advantages of plastic fasteners over metal fasteners.

a. ____

b. ____

c. ____

22. Select devices to lock components on a shaft by placing an "X" in the appropriate blanks.

______a. Woodruff key

______b. Cleavage pin

______c. Cotter key

______d. Joggle clamp

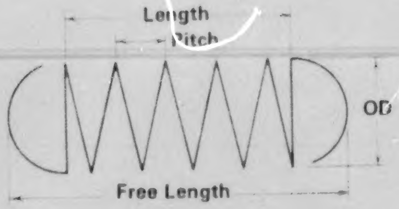
23. List three types of springs.

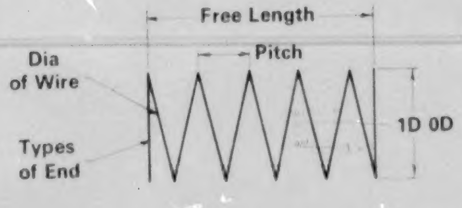
a. ____

b. ____

c. ____

24. Identify types of springs according to notes and dimension.


Length
Pitch
OD
Free Length


Free Length
Dia
of Wire
Pitch
1D 0D
Types
of End

a. ____________________ b. ____________________

25. Name two types of spring clips.

a. ____

b. ____

26. Select types of keys to prevent relative motion between wheel and shaft by placing an "X" in the appropriate blanks.

_____a. Flat

_____b. Square

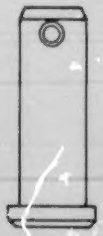
_____c. Knurled

_____d. Torsion

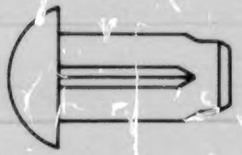
_____e. Dart-type

_____f. Woodruff

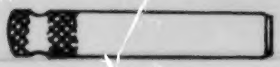
27. Identify types of machine pins.



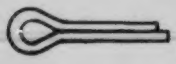
a. ______________________________



b. ______________________________



c. ______________________________



d. ______________________________

28. Select true statements concerning washers by placing an "X" in the appropriate blanks.

_____a. Conical washers have spring action

_____b. Spring washers have built-in pressure

_____c. Tooth lock washers are used mainly for bearing surface

_____d. Helical spring washers are locking

29. List two applications of inserts.

a. ______________________________

b. ______________________________

30. Distinguish between types of lock washers by placing an "X" next to the helical spring washers and an "O" next to the tooth lock washers.

_____a. Plain

_____b. Dome

_____c. External

_____d. Countersunk

_____e. Nonlink positive

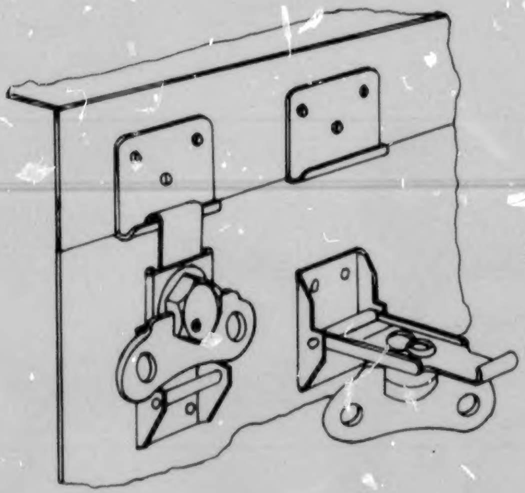
_____f. Dished

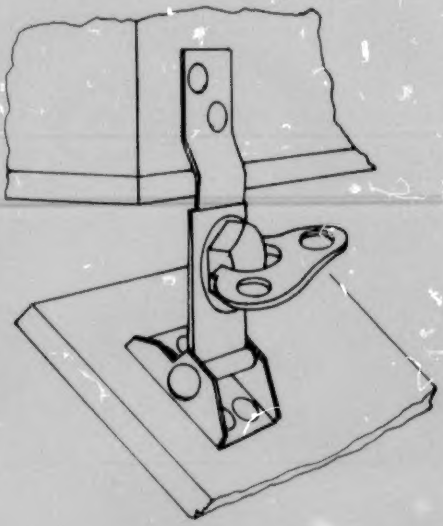
31. Name two uses for spring washer designs.

a. ______________________________

b. ______________________________

32. Identify quick opening and locking devices.





a. ____________________ b. ____________________

33. Match the miscellaneous machine elements on the right with the correct uses.

______a. To allow fastening with fingers

______b. To weld studs to a surface

______c. To rapidly assemble and disassemble parts

______d. To prevent rotation of nuts

______e. To weld nuts to a surface

______f. To prevent leaks at joints

______g. To cut mating thread in metal or plastic

1. Quick release pins
2. Projection weld fasteners
3. Spot weld fasteners
4. Stud welded fasteners
5. Self-tapping screws
6. Captive nuts
7. Wing nuts

34. Name four advantages of welding over threaded fasteners.

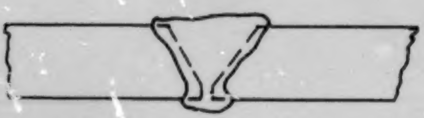
a. ______________________________

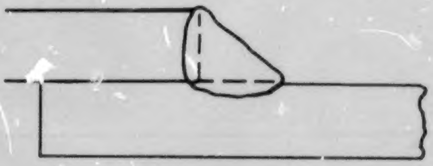
b. ______________________________

c. ______________________________

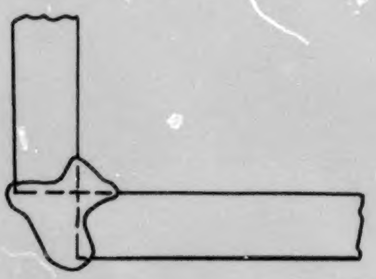
d. ______________________________

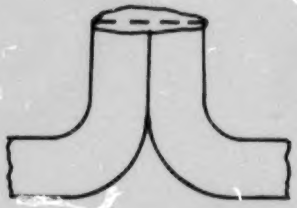
35. Identify types of welded joints.





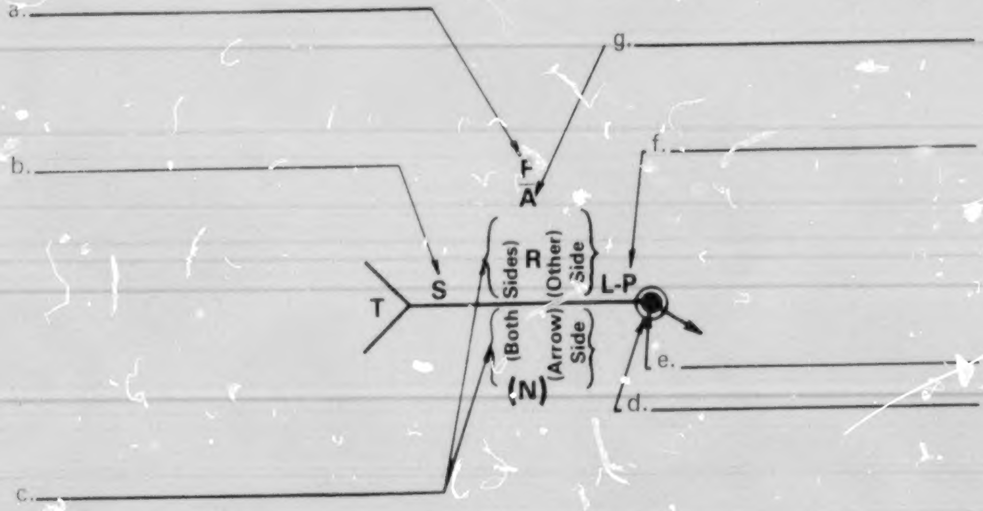
a. ____________________ b. ____________________



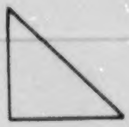


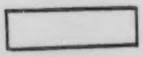
c. ____________________ d. ____________________

36. Label parts of a welding symbol.

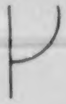

a.
g.
b.
f.
F
A
T
S
R
(Both Sides)
(Other) Side
(Arrow) Side
L-P
(N)
e.
d.
c.

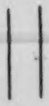
37. Identify basic arc and gas weld symbols.





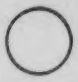
a. ______________________ b. ______________________

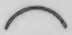




c. ______________________ d. ______________________

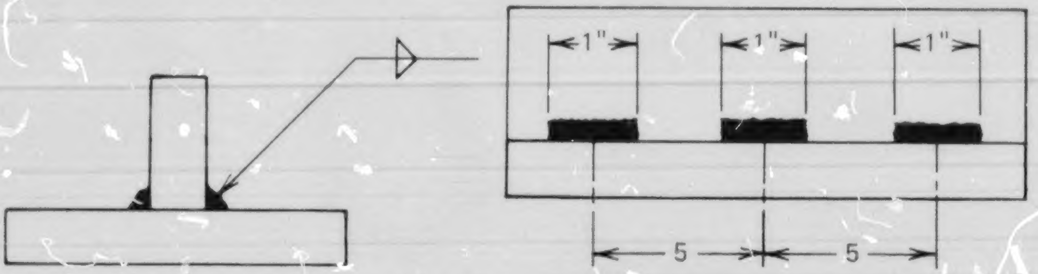
38. Identify supplementary welding symbols.



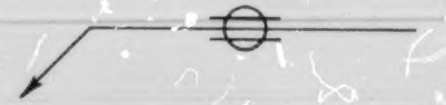


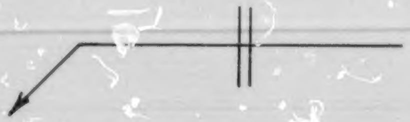
a. ______________________ b. ______________________

39. Determine welding dimensions for the following fillet weld.



40. Identify resistance welding symbols.





a. ______________________ b. ______________________

41. Name two classifications of methods of using adhesives for bonding materials.

a. ______________________

b. ______________________

42. List two joint design considerations for adhesive bonding.

a. ______________________

b. ______________________

43. Select joint designs for adhesive bonding by placing an "X" in the appropriate blanks.

______a. Lap joint

______b. Joggle joint

______c. Resistance joint

______d. Corner joint

______e. Simplified joint

44. Demonstrate the ability to:

a. Construct thread symbols.

b. Construct bolts, screws, and nuts.

c. Construct an assembly containing various fasteners.

d. Construct a welded assembly drawing.

e. Construct spring drawings to include specifications.

f. Construct keys in assembled positions.

g. Write specifications for hardware from vender catalogs.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

FASTENERS AND HARDWARE
UNIT VI

ANSWERS TO TEST

1. a. 8
   b. 4
   c. 17
   d. 21
   e. 13
   f. 29
   g. 1
   h. 7
   i. 9
   j. 3
   k. 25
   l. 19
   m. 14
   n. 12
   o. 5
   p. 11
   q. 16
   r. 20
   s. 22
   t. 27
   u. 26
   v. 6
   w. 24
   x. 2
   y. 28
   z. 10
   aa. 23
   bb. 15
   cc. 18

2. a. Removable
   b. Permanent

3. a. Holding parts together
   b. Adjustment
   c. Power transmission

4. a. Depth
   b. Crest
   c. Root
   d. Side
   e. Minor diameter
   f. Pitch diameter
   g. Major diameter
   h. Pitch
   i. Thread angle

5. a. Sharp V
   b. American National
   c. Unified
   d. Square
   e. Acme
   f. Whitworth Standard
   g. Metric
   h. Knuckle
   i. Buttress

6. a. L = 1/10
   b. L = 2/18 = 1/9
   c. L = 3/24 = 1/8

7. a. Detailed
   b. Schematic
   c. Simplified

8. a. 2
   b. 3
   c. 1

9. a. Coarse
   b. Fine

10. a. Major diameter
    b. Threads per inch
    c. Class of fit
    d. Left hand
    e. Thread depth
    f. Metric
    g. Major diameter in mm
    h. Pitch in mm
    i. Class of fit
    j. Internal thread

11. a. O
    b. X

12. Any four of the following:

    a. Bolts
    b. Studs
    c. Cap screws
    d. Machine screws
    e. Set screws

13. a. Hexagon head
    b. Square head

14. b, c, f

15. Any four of the following:

    a. Hexagon head
    b. Flat head
    c. Round head
    d. Fillister head
    e. Hex socket head

16. b. Flat head

17. a. Flat point
    b. Hex socket head
    c. Full dog point
    d. Half dog point

18. a. Eye bolt
    b. Step bolt
    c. Square neck bolt
    d. Clevis
    e. Wing nut
    f. Tapping screw

19. a. Button head
    b. Cone head
    c. Countersunk head
    d. Button head

20. a. 4
b. 2
c. 5
d. 1
e. 3

21. Any three of the following:

a. Lightweight
b. Thermal and electrical insulators
c. Corrosion resistant
d. Easy to color

22. a, c

23. Any three of the following:

a. Compression
b. Flat
c. Extension
d. Torsion

24. a. Extension
b. Compression

25. Any two of the following:

a. Spring molding
b. Stud receiver
c. Cable, wire, and tube
d. Dart-type
e. U-shaped, S-shaped, and C-shaped

26. a, b, f

27. a. Clevis
b. Drive
c. Knurled
d. Cotter

28. a, b, d

29. Any two of the following:

a. In light alloys and plastics for higher strength
b. In ferrous alloys for permanent threads
c. In thin parts for internal locking of threaded holes
d. In reassembly of mating screw without damage to metal

30. a. X   d. O
b. O   e. X
c. O   f. O

31. Any two of the following:
    - a. Provide pressure on adjacent parts
    - b. Act as take-up devices in an assembly
    - c. Control end pressure
    - d. Eliminate end play

32. a. Link lock
    b. Hinge lock

33. a. 7
    b. 3
    c. 1
    d. 6
    e. 2
    f. 4
    g. 5

34. Any four of the following:
    - a. Fast and relatively simple process
    - b. Savings in time and expense
    - c. Less weight than casting or forged part in most cases
    - d. Neater appearance
    - e. Less noisy
    - f. Painting simplified
    - g. Small quantity jobs

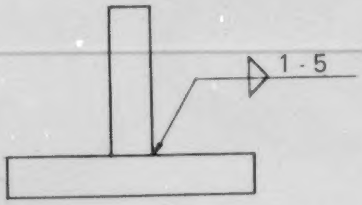
35. a. Butt
    b. Lap
    c. Corner
    d. Edge

36. a. Finish symbol
    b. Size or strength for resistance welds
    c. Basic weld symbol
    d. Weld-all-around symbol
    e. Field weld symbol
    f. Pitch of welds
    g. Groove angle

37. a. Fillet
    b. Plug or slot
    c. J groove
    d. Square groove

38. a. Weld-all-around
    b. Convex contour

39.



40. a. Resistance seam
    b. Flash or upset

41. Any two of the following:

    a. Functional
    b. Chemical
    c. Method of application
    d. Nature of properties

42. a. Consider type of stresses on bonded joint
    b. Use as large of contact areas as possible for maximum strength

43. a, b, d

44. Evaluated to the satisfaction of the instructor

PRESENTATION DRAWINGS
UNIT VII

UNIT OBJECTIVE

After completion of this unit, the student should be able to sketch and draw presentation drawings. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment sheets and by scoring 85 percent on the unit test.

(NOTE: Students should review "Axonometrics," "Oblique," and "Perspective" of *Basic Drafting, Book Two* before attempting this unit.)

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to presentation drawings with the correct definitions.
2. Name three types of presentation sketches.
3. Arrange in order the steps of sketching.
4. Select true statements concerning ellipse construction.
5. List places where presentation drawings are found.
6. Complete a list of shading techniques for presentation drawings.
7. Distinguish between the types of axonometric drawings.
8. Select true statements concerning oblique drawings.
9. Match parts of exploded assembly presentation drawings with the correct uses.
10. Select special requirements for patent drawings.
11. Demonstrate the ability to:
    a. Shade pictorials.
    b. Construct conceptual presentation sketches.
    c. Construct design sketches.
    d. Construct a dimetric presentation drawing.
    e. Construct an oblique presentation drawing.
    f. Construct a two point presentation perspective of an object.
    g. Construct an exploded assembly presentation drawing.

PRESENTATION DRAWINGS
UNIT VII

SUGGESTED ACTIVITIES

I. Provide students with objective sheet.

II. Provide students with information and assignment sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Suggest alternate problems for use in Assignment Sheet #1.

VII. Allow students to select projects they have an interest in for the conceptual sketches.

VIII. Allow students to show and discuss their ideas in front of the class.

IX. Several solutions could be submitted for each problem by each student in Assignment Sheet #2.

X. Have students discuss advantages and disadvantages of each problem in Assignment Sheet #2

XI. Recommend that students work in teams and trace other students' parts for the exploded assembly. This will allow larger projects to be completed if time is a problem.

XII. Impose a time limit to force students to think fast and draw fast.

XIII. Have students construct three point perspectives after they have constructed two point perspectives.

XIV. Have students select problems for Assignment Sheet #7 from past set of assembly drawings.

XV. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM 1--Reduction Ratios
2. TM 2--Sketching Order

   2A--Overlay

   2B--Overlay
3. TM 3--Ellipses
4. TM 4--Catalog Presentation Drawing
5. TM 5--Sales Literature Presentation Drawings
6. TM 6--Technical Report Presentation Drawings
7. TM 7--Shades and Shadows
8. TM 8--Shades and Shadows (Continued)
9. TM 9--Shades and Shadows (Continued)
10. TM 10--Axonometric Drawings
11. TM 11--Oblique Drawings
12. TM 12--Leaders and Overlapping Parts
13. TM 13--Exploded Assembly Drawing
14. TM 14--Exploded Assembly Drawing (Continued)
15. TM 15--Patent Drawing

D. Assignment sheets

1. Assignment Sheet #1--Shade Pictorials
2. Assignment Sheet #2--Construct Conceptual Presentation Sketches
3. Assignment Sheet #3--Construct Design Sketches
4. Assignment Sheet #4--Construct a Dimetric Presentation Drawing
5. Assignment Sheet #5--Construct an Oblique Presentation Drawing
6. Assignment Sheet #6--Construct a Two Point Presentation Perspective of an Object
7. Assignment Sheet #7--Construct an Exploded Assembly Presentation Drawing

E. Test

F. Answers to test

II. References:

A. Giesecke, Frederick E., et al. *Technical Drawing.* New York, 10022: Macmillan Publishing Co., Inc., 1980.

B. Thomas, TA. *Technical Illustration.* New York: McGraw-Hill Book Co., 1972.

C. Spence, William P. *Drafting Technology and Practice.* Peoria, IL 61614. Charles A. Bennett Co., Inc.

D. Hoelscher, R. P., Clifford Springer, and Richard Pohle. *Industrial Production Illustration.* New York: McGraw-Hill Book Co., 1946.

(NOTE: This book is out of print and may be difficult to find.)

E. *Guide for Patent Draftsmen.* Washington, D.C.: U.S. Department of Commerce, Patent and Trademark Office.

(NOTE: This can be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.)

F. *The Kodak Compass.* Eastman Kodak Company, Rochester, NY 14650.

PRESENTATION DRAWINGS
UNIT VII

INFORMATION SHEET

I. Terms and definitions

   A. Freehand technical sketching--Freehand drawing of technical ideas without instruments

   B. Conceptual sketches--Recording and communicating technical ideas that are in the process of development

   C. Design sketches--Carefully drawn sketches prepared to be given to someone else to make detail drawings

   D. Presentation sketch or drawing--Sketch, mechanical drawing, or rendering designed to illustrate a technical subject and help sell or clarify its idea to a client

   E. Pictorial drawing--Three dimensional drawing in axonometric, oblique, or perspective to imitate a picture of an object

   F. Shading--Simple exterior embellishments utilizing light effects to enhance the pictorial qualities of an object

   G. Exploded assembly drawing--Drawing showing all parts in relationship with each other and how they fit together

   H. Photodrafting--A simplified drafting technique to reduce drafting time that combines photographs and line drawing on a standard sheet layout

   I. Paste-up drafting--A simplified drafting technique in which drawing segments are pasted or typed in position on a drawing form and photographically reproduced

   J. Patent drafting--Drawing an invention in pictorial and explanatory form to convey the correct interpretation

   K. Airbrushing--A method of touching up photographs and adding shading to line drawings by blowing ink or paint pigments through an air cap onto the drawing

   L. Reduction ratios--To reduce a drawing proportionally using a ratio (Transparency 1)

II. Types of presentation sketches

   A. Conceptual

   B. Design

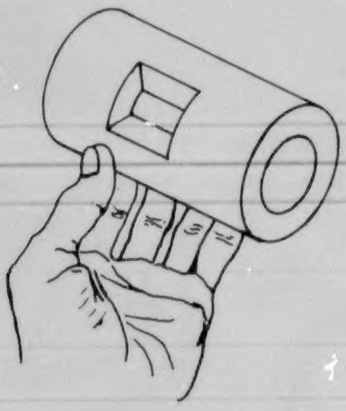
   C. Presentation

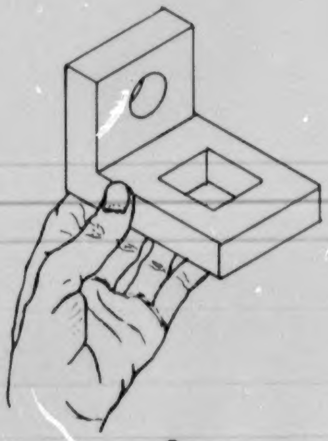
INFORMATION SHEET

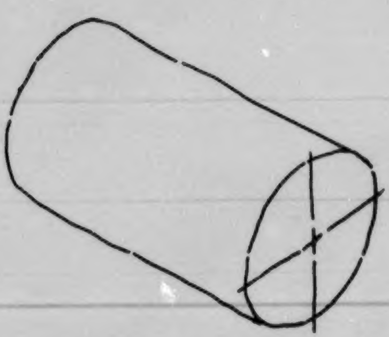
III. Steps of sketching (Transparency 2)

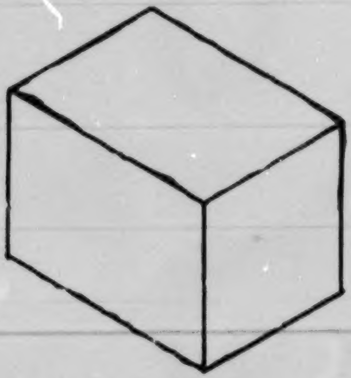
A. Sketch light construction of an enclosing box or cylinder in proportion

Example:



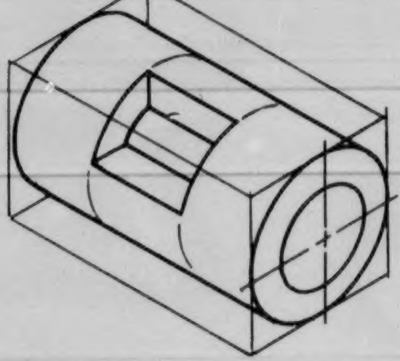


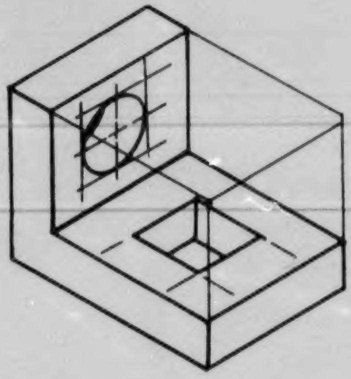




B. Block in object proportionately with light construction lines

Example:

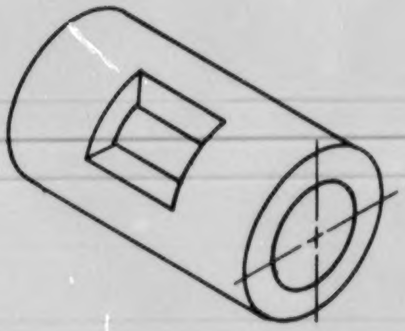


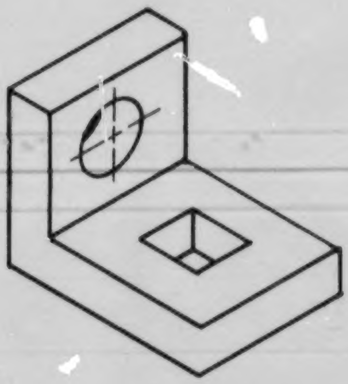


INFORMATION SHEET

C. Clean up unnecessary construction lines with an eraser and darken final visible lines

Example:

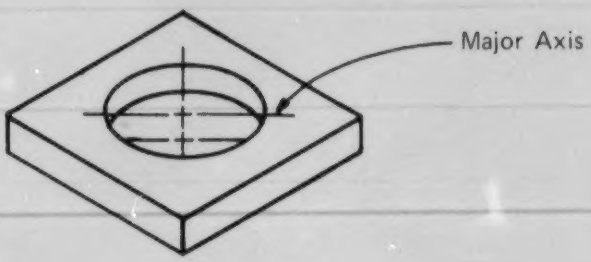




IV. Ellipse construction (Transparency 3)

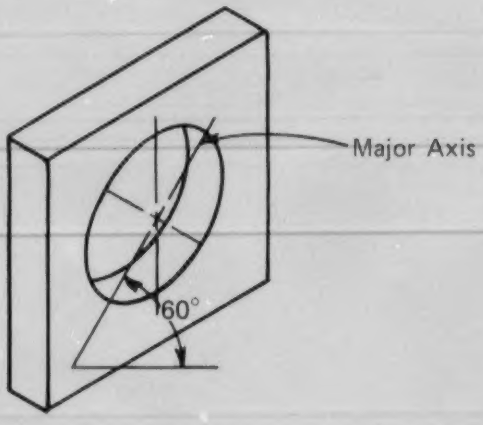
A. On horizontal (top) plane, major axis is horizontal

Example:



B. On right side plane, major axis is 60° from horizontal

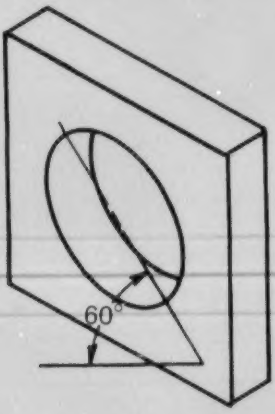
Example:



INFORMATION SHEET

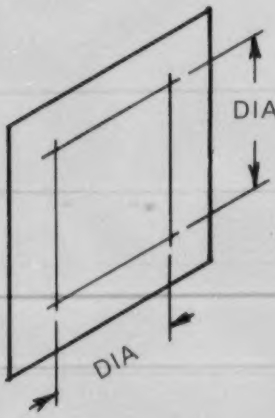
C. On left side plane, major axis is 60° from horizontal

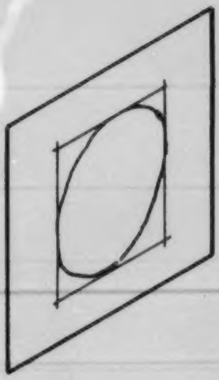
Example:



D. Diameter of circle is boxed in, and ellipse is sketched

Example:

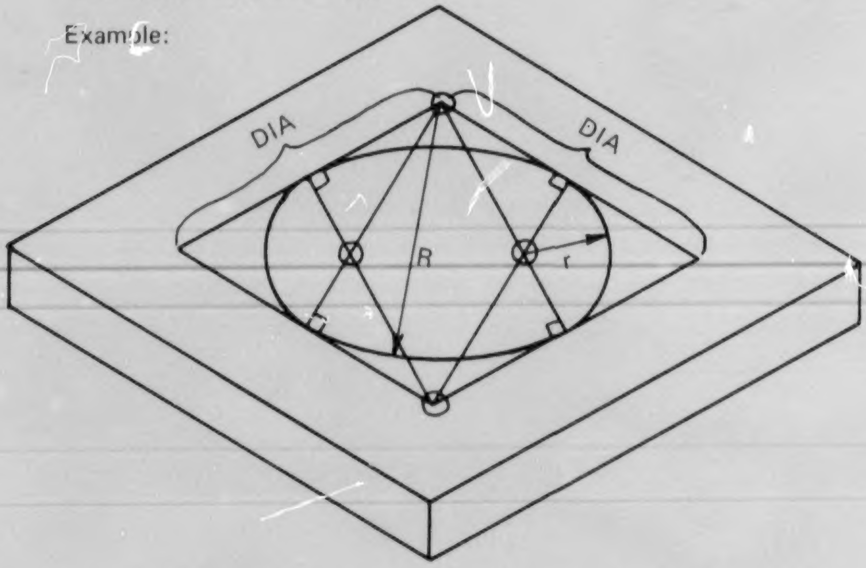




INFORMATION SHEET

E. Perpendicular bisector of each side of box is found and drawn mechanically with straight edge and compass

Example:



V Places where presentation drawings are found (Transparencies 4, 5, and 6)

A. Catalogs

B. Sales literature

C. Proposals

D. Technical reports

E. Patents

F. Parts books

VI. Shading techniques for presentation drawings (Transparencies 7, 8, and 9)

A. Lines

B. Dots-stippling

C. Smudge

D. Transfer sheets

E. Air brush

F. Shadows

INFORMATION SHEET

VII. Types of axonometric drawings (Transparency 10)

- A. Isometric
    1. Width, height, and depth on equal scale
    2. All angles are equal
    3. 120° between axes
- B. Dimetric
    1. Width and height full scale
    2. Two angles are equal
    3. Two dimensions are equal
- C. Trimetric
    1. Width, height, and depth are unequal
    2. All axes are at different angles
    3. All angles are unequal
    4. Dimensions are unequal

VIII. Oblique drawings (Transparency 11)

- A. Cavalier--True length on all axes
- B. Cabinet--Half scale on depth axis
- C. General--Depth axis at any scale

    (NOTE: Circular view is normally drawn in front view--true size view.)

IX. Parts of exploded assembly presentation drawings and uses (Transparencies 12, 13, and 14)

- A. Methods of identification of parts
    1. Numbers--Used if tied to parts list
    2. Part names--Used if immediate identification is important

        (NOTE: Either method may be used on exploded assembly presentation drawings. If the numbers method is used, there must be a corresponding parts list.)

INFORMATION SHEET

B. Flow lines--Indicate where parts fit

C. Shading--Used to differentiate one part from another

D. Standard hardware--Can be duplicated and pasted up on drawing to save time

E. Axis--Should be in natural position rather than just to fit the paper

F. Parts list (PL)--Should be on same sheet directly above title block

G. Overlapping parts--Lines in front take precedence over lines in back by gapping back lines for front lines

(NOTE: For best results drawing should be inked and reduced for final copy.)

X. Special requirements for patent drawings (Transparency 15)

A. Draw mechanically correct to help understand the invention

B. Do not dimension or detail as working drawings

C. Illustrate each claim

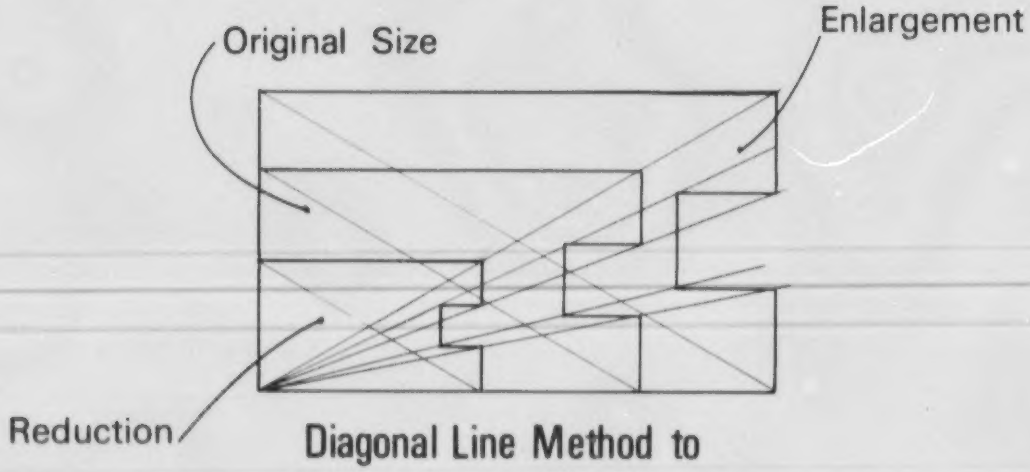
D. Omit center lines and notes

E. Draw in India ink or equivalent

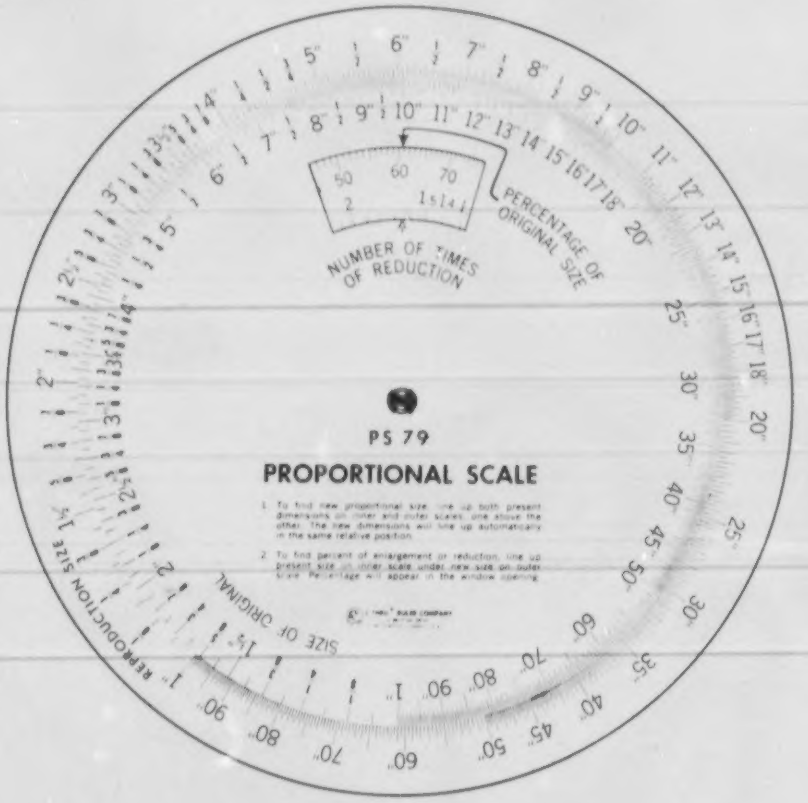
F. Use heavy, smooth, white paper 8 1/2 by 14" (21.6 by 35.6 cm) or 21.0 by 29.7 cm (DIN size A4); two ply or three ply bristol board is preferred

G. Line shade and surface shade to improve readability

Reduction Ratios


Original Size
Enlargement
Reduction

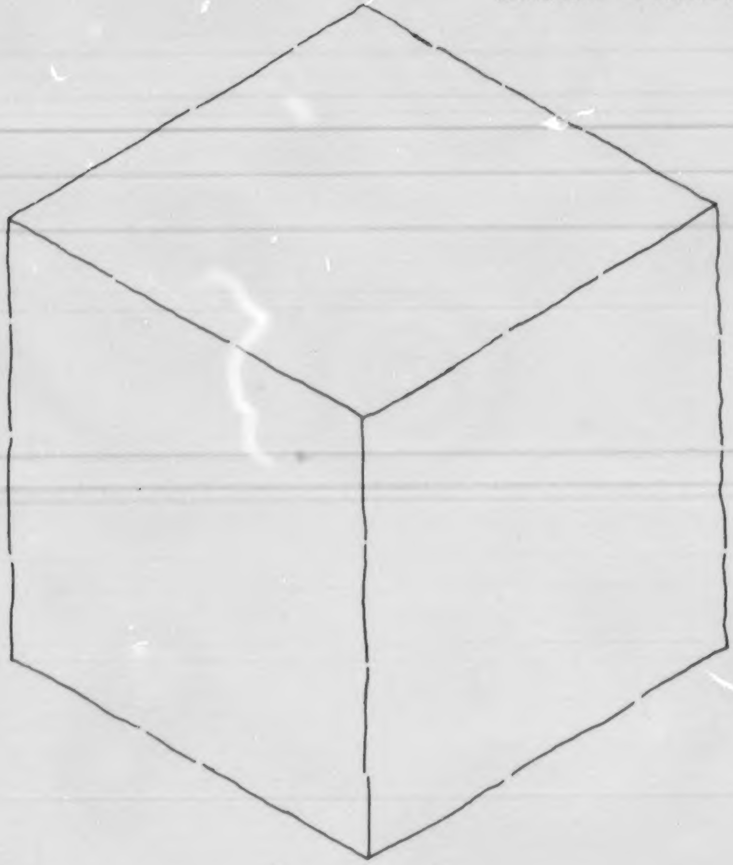
Diagonal Line Method to Enlarge or Reduce


PS 79
PROPORTIONAL SCALE
NUMBER OF TIMES OF REDUCTION
PERCENTAGE OF ORIGINAL SIZE
SIZE OF ORIGINAL
REPRODUCTION SIZE
50
60
70

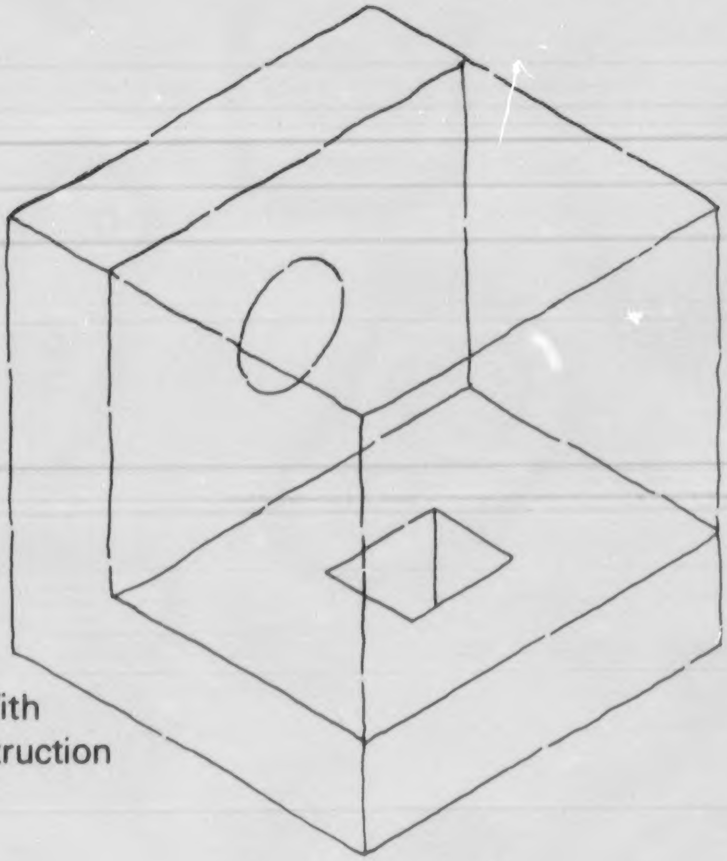
1. To find new proportional size, line up both present dimensions on inner and outer scales, one above the other. The new dimensions will line up automatically in the same relative position.
2. To find percent of enlargement or reduction, line up present size on inner scale under new size on outer scale. Percentage will appear in the window opening.

Circular Proportional Scale

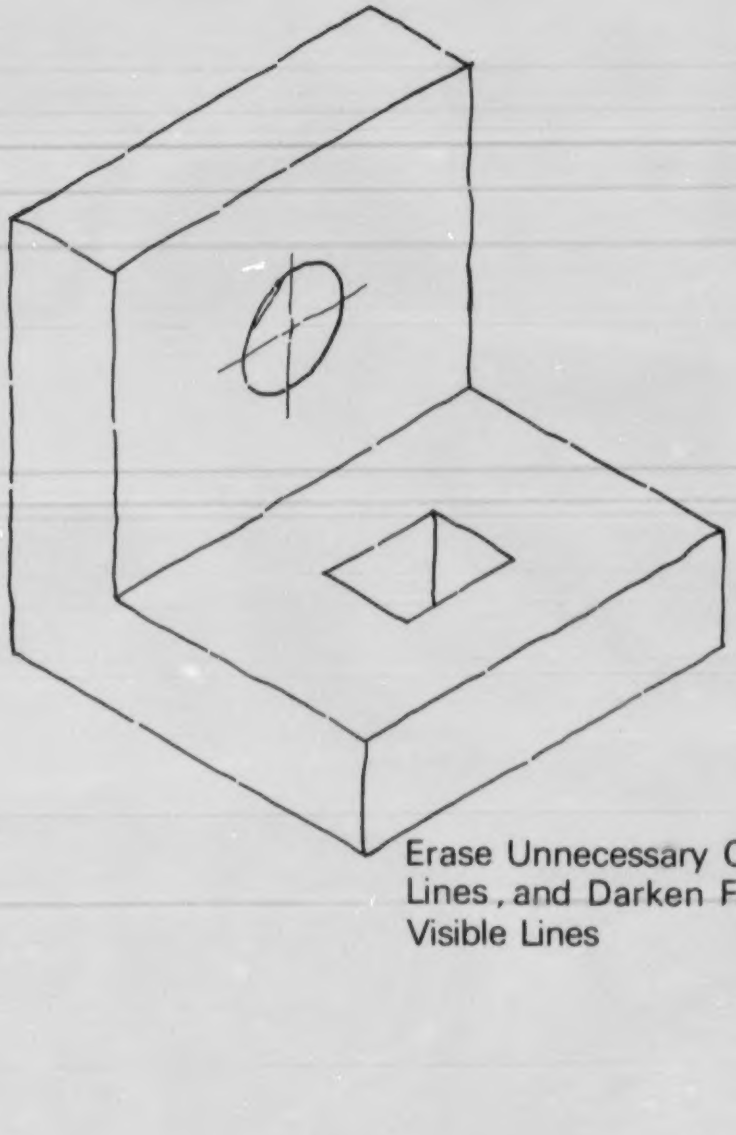
Sketching Order



Sketch Enclosing Box

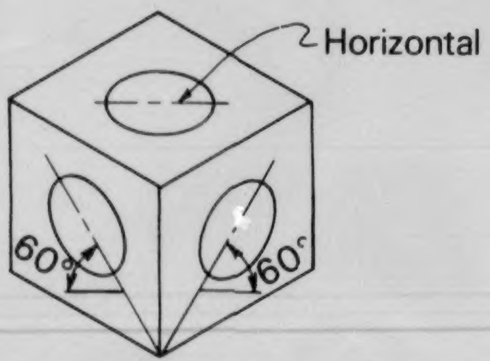


Block in With
Light Construction
Lines

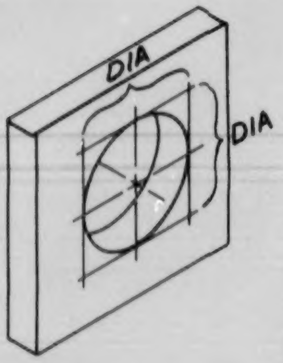


Erase Unnecessary Construction Lines, and Darken Final Visible Lines

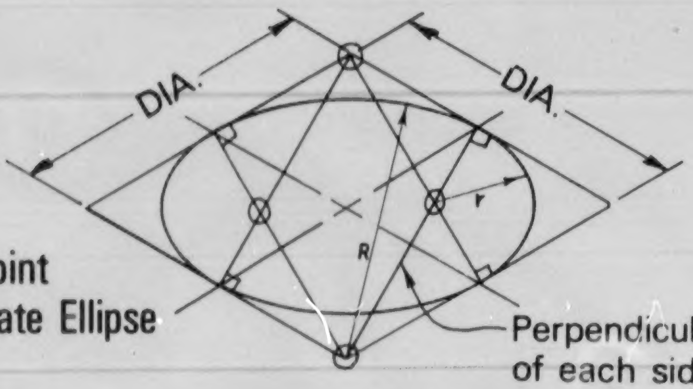
Ellipses


Horizontal
60°
60°

Ellipse Orientation

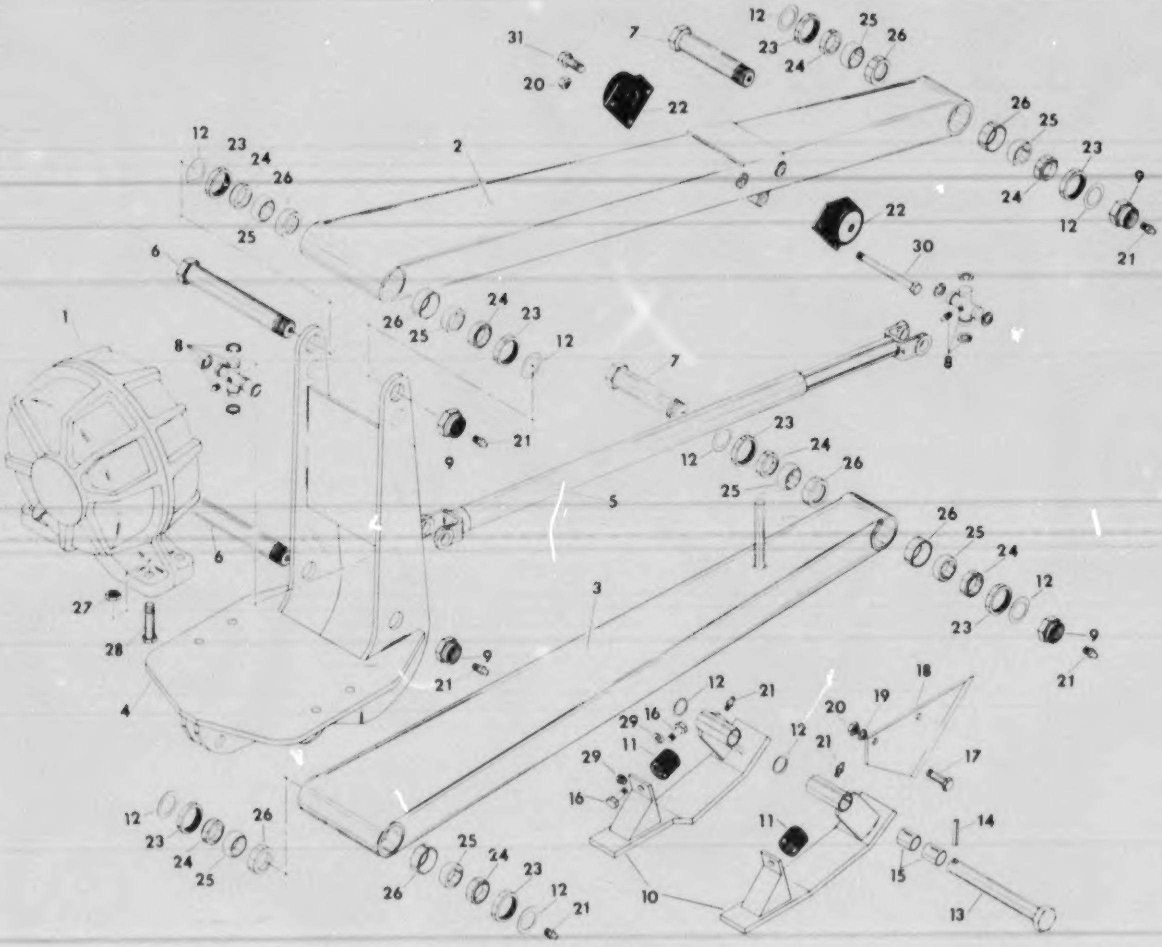


Sketch Box


DIA.
DIA.
r
R
Perpendicular Bisectors of each side

4 Point
Approximate Ellipse

Catalog Presentation Drawing


31
20
7
22
12
23
24
25
26
12
23
24
26
25
2
26
25
23
24
12
9
21
22
30
6
26
25
24
23
12
1
8
7
8
9
21
23
12
24
26
25
5
6
26
25
24
12
23
9
21
3
27
28
9
21
4
12
21
29
16
11
12
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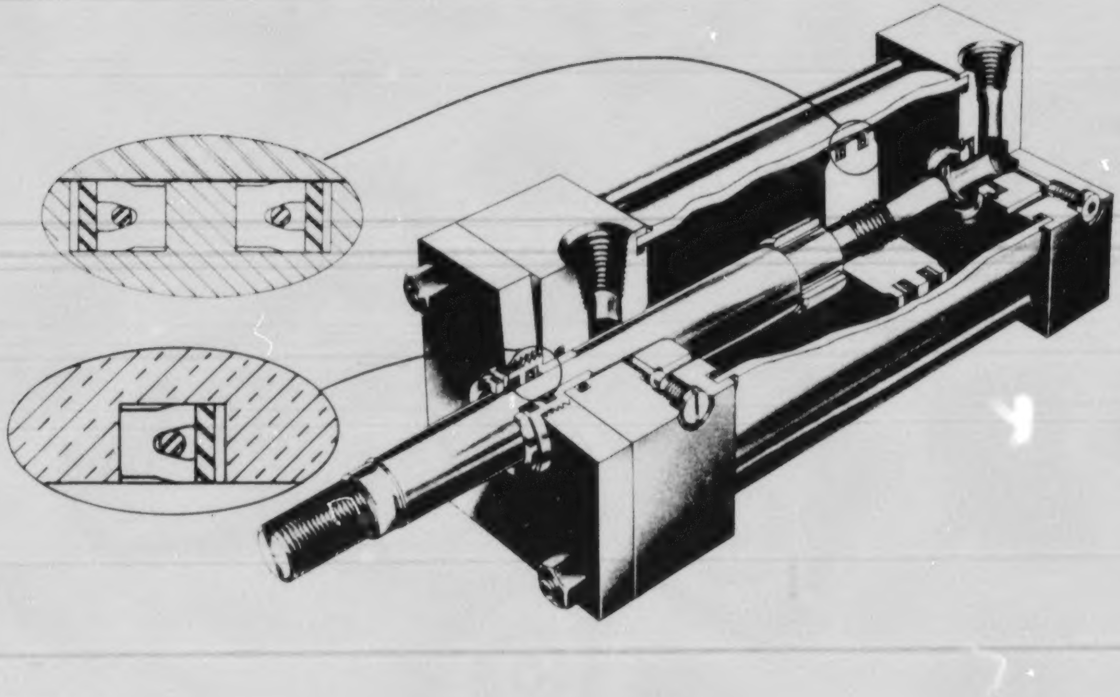
19
18
21
29
16
17
11
14
15
10
13
12
23
24
25
26
25
24
23
12
26
21

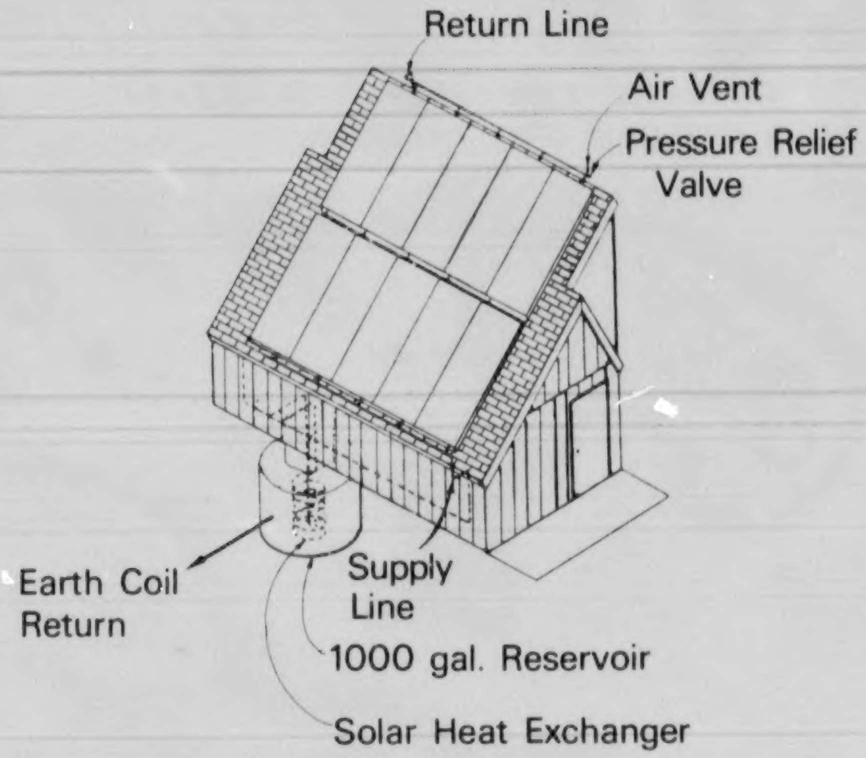
PLOW FRAME

Courtesy of Charles Machine Works, Perry, Oklahoma

Sales Literature Presentation Drawing



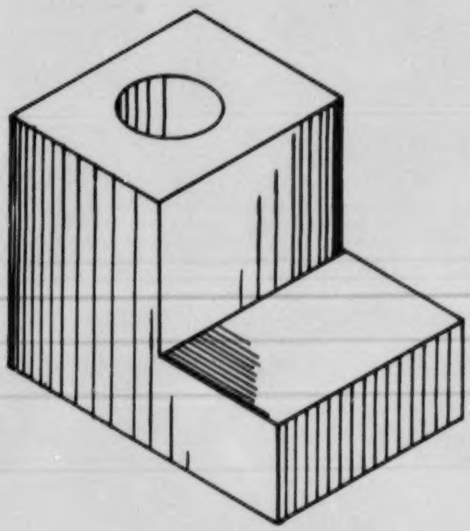
Technical Report Presentation Drawing


Return Line
Air Vent
Pressure Relief Valve
Earth Coil Return
Supply Line
1000 gal. Reservoir
Solar Heat Exchanger

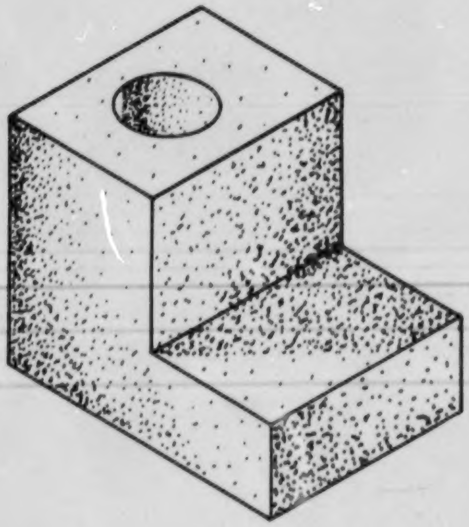
Solar Hut and Earth Coil Reservoir

Courtesy of Dr. James Bose, Oklahoma State University

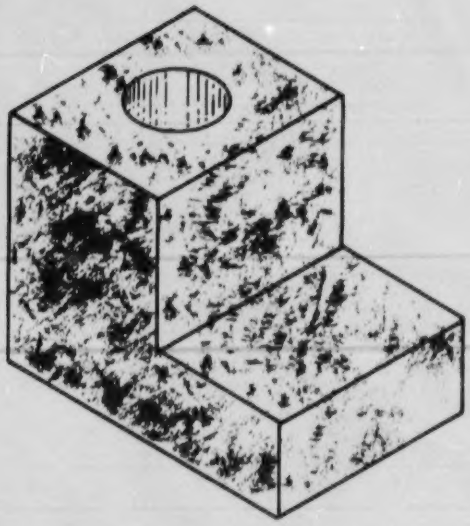
Shades and Shadows



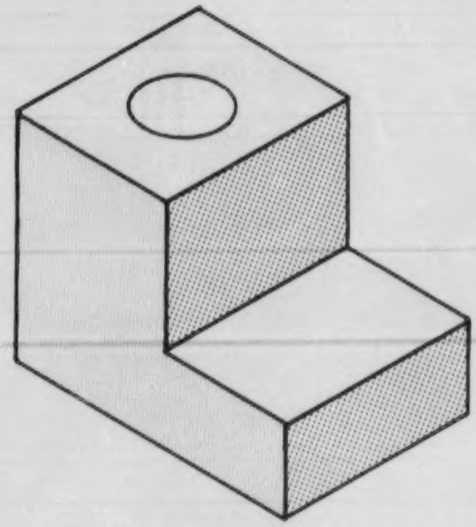
Line Shading



Dots

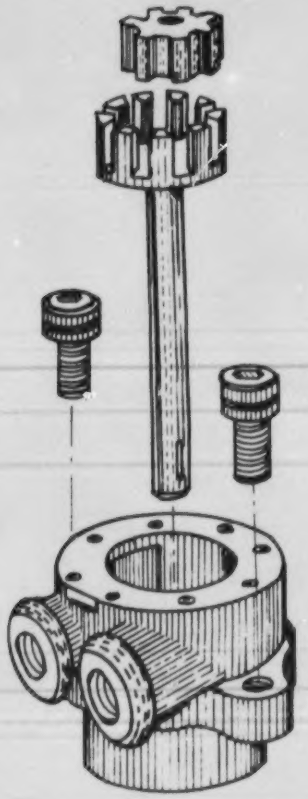


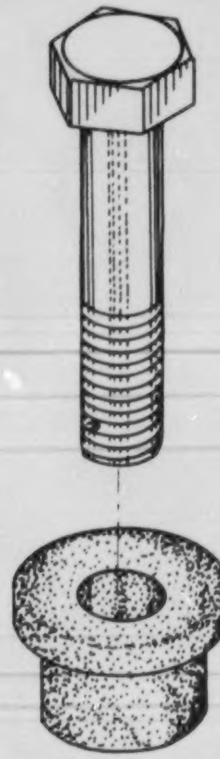
Smudge Shading

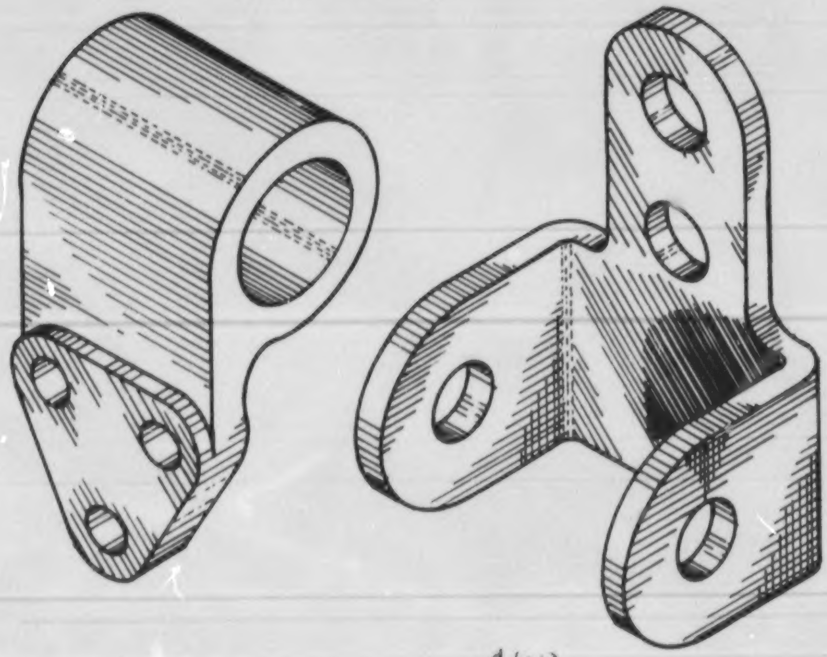


Press on Materials

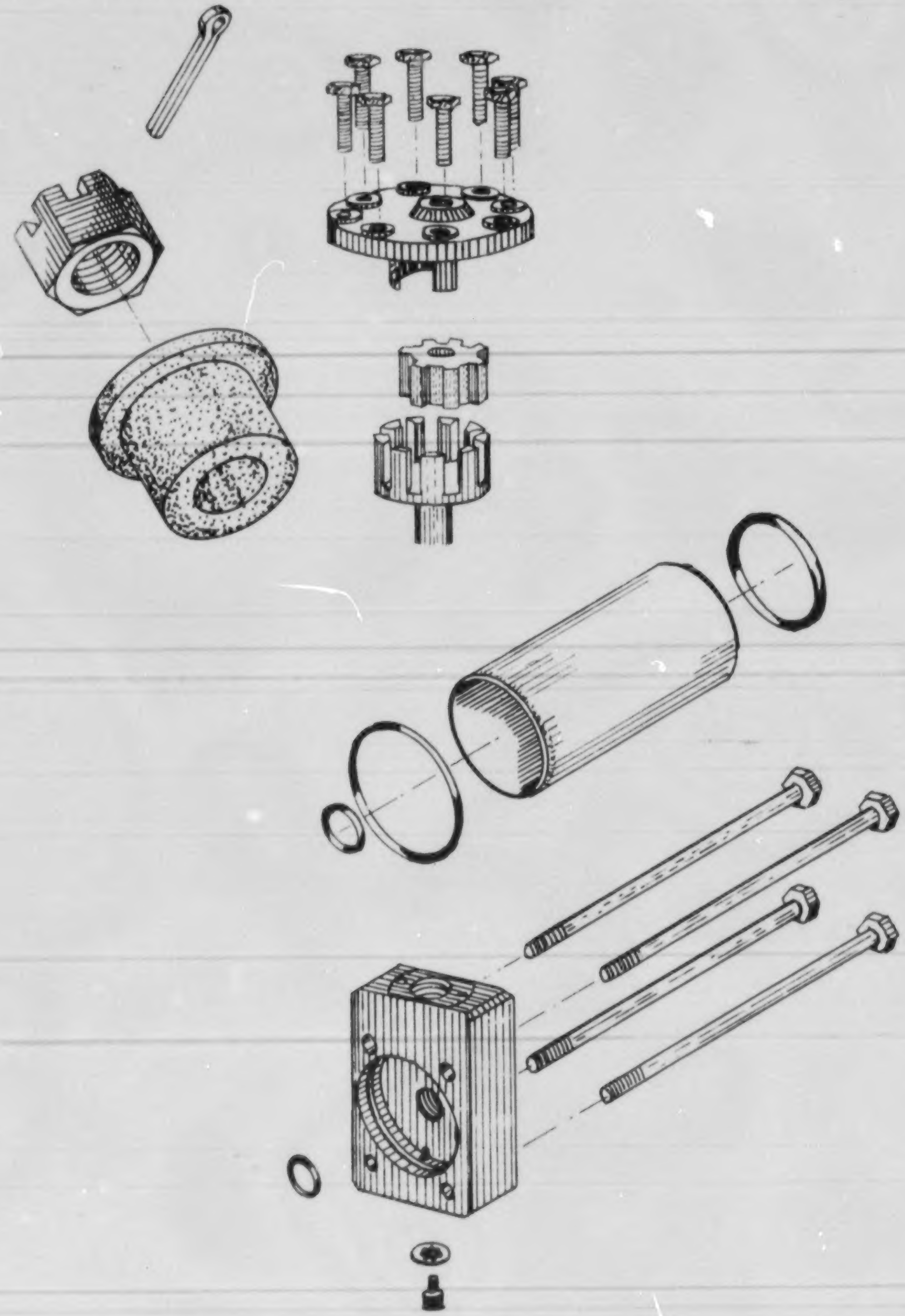
Shades and Shadows (Continued)



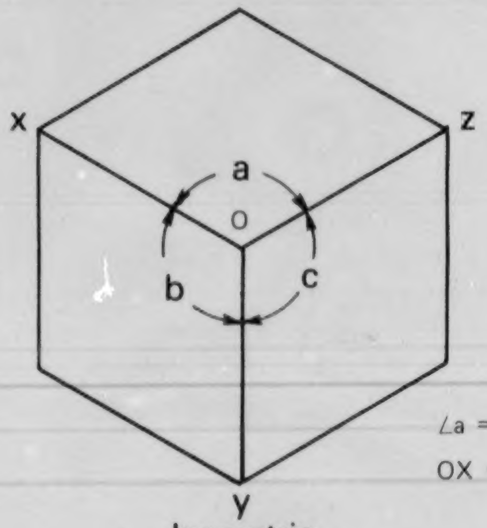




Shades and Shadows (Continued)



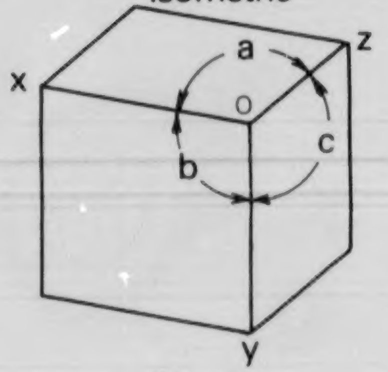
Axonometric Drawings



Isometric

∠a = ∠b = ∠c

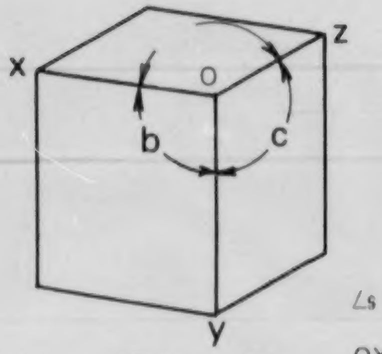
OX = OY = OZ



Dimetric

∠a = ∠c

OX = OY

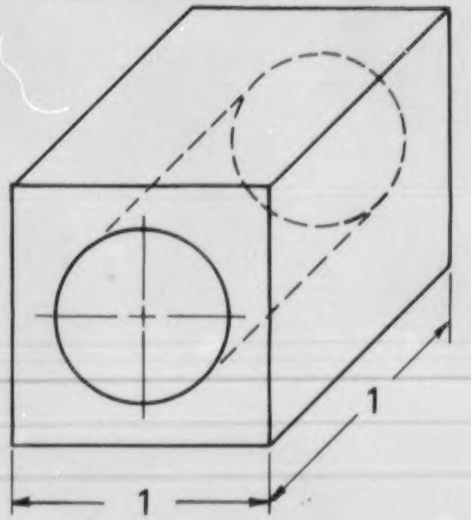


Trimetric

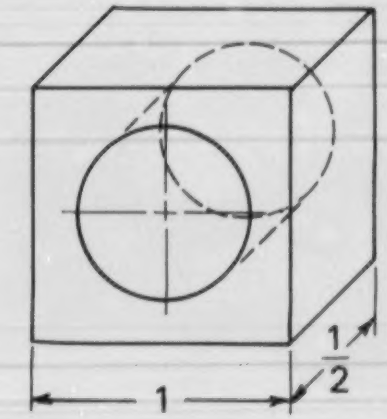
∠s a, b, and c are unequal

OX, OY, and OZ are unequal

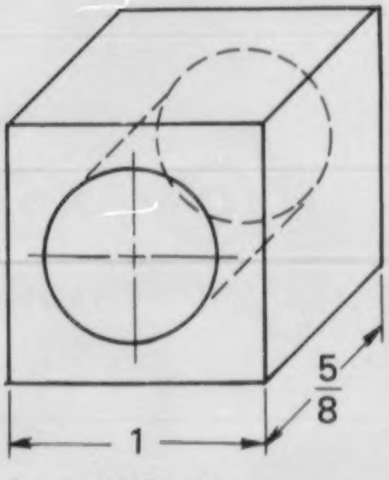
Oblique Drawings



Cavalier Oblique

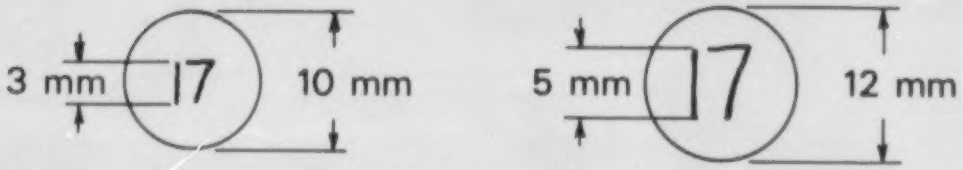


Cabinet Oblique

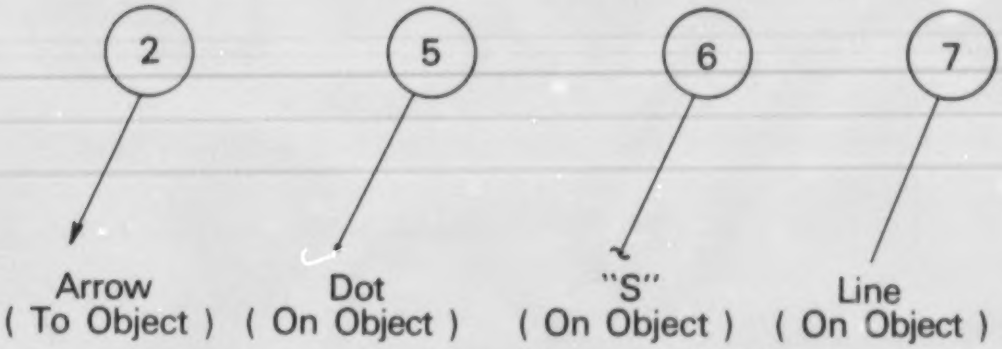


General Oblique

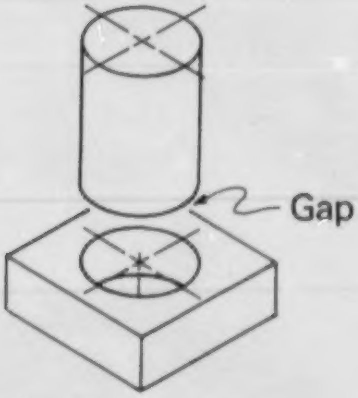
Leaders and Overlapping Parts


3 mm
17
10 mm
5 mm
17
12 mm

Identification Numbers

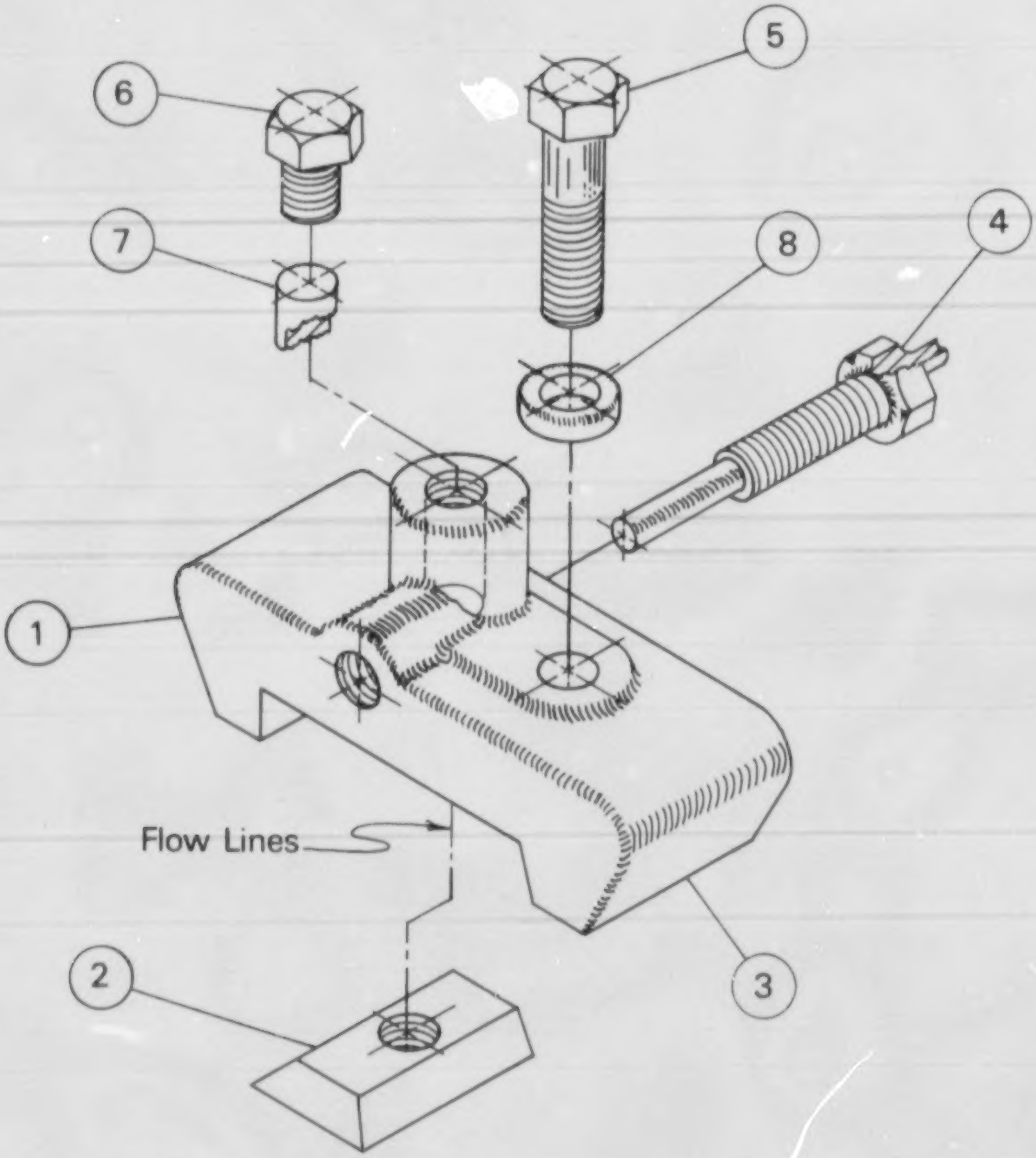

2
5
6
7
Arrow
(To Object)
Dot
(On Object)
"S"
(On Object)
Line
(On Object)

Leaders



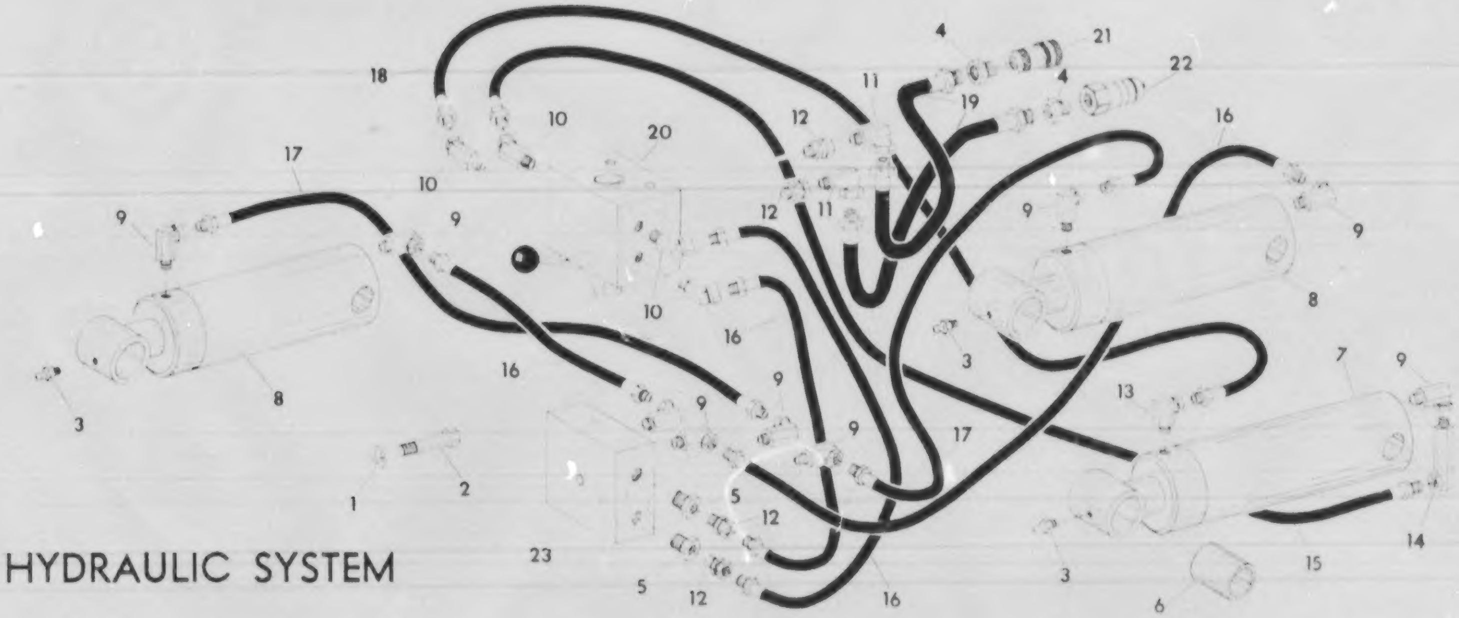
Overlapping Parts

Exploded Assembly Drawing


5
6
7
8
4
1
Flow Lines
2
3

Exploded Assembly Drawing

(Continued)


18
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21
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22
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16
9
9
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3
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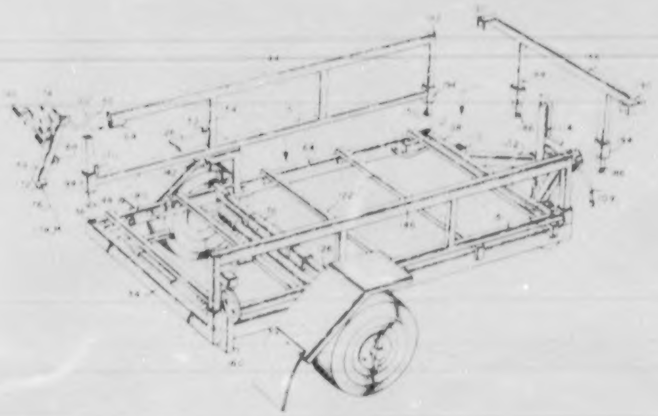
9
9
17
13
7
9
1
2
5
12
23
5
12
16
3
6
15
14

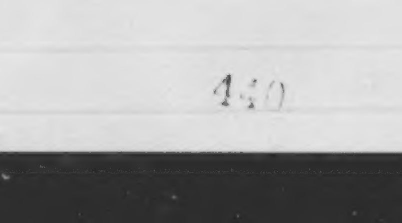
HYDRAULIC SYSTEM

Patent Drawing

3,623,744
COLLAPSIBLE TRAILER APPARATUS
Melvin C. Bertness, Santa Cruz, and Arnold E. Lyle, Capitola, both of Calif., assignors to Bermaco Enterprises, San Jose, Calif.
Filed Dec. 11, 1969, Ser. No. 884,240
Int. Cl. B62d *23/00*
U.S. Cl. 280—106 12 Claims



222,660
ELECTRIC SCISSORS
John K. Miles, Columbus, Ind., and Jack F. Baker, Glenview, Ill., assignors to Arvin Industries, Inc., Columbus, Ind.
Filed Aug. 12, 1970, Ser. No. 24,433
Term of patent 14 years
Int. Cl. D8—*03*
U.S. Cl. D8—61



PRESENTATION DRAWINGS
UNIT VII

ASSIGNMENT SHEET #1--SHADE PICTORIALS

Directions: On "B" size vellum or other media selected by instructor, construct an isometric drawing of one of the problems below to appropriate scale using pencil or ink. Make four quality blueline prints, and shade each blueline print using a **different** shading technique.

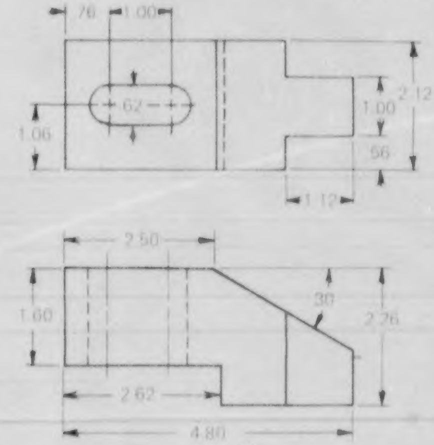
(NOTE: These techniques are outlined in the information sheet, and include lines, stipples, and smudging.)

Shade the original drawing using the **best** shading technique on the prints. Make a blueline print of the completed drawing, and turn in all blueline prints to instructor.

Problems:

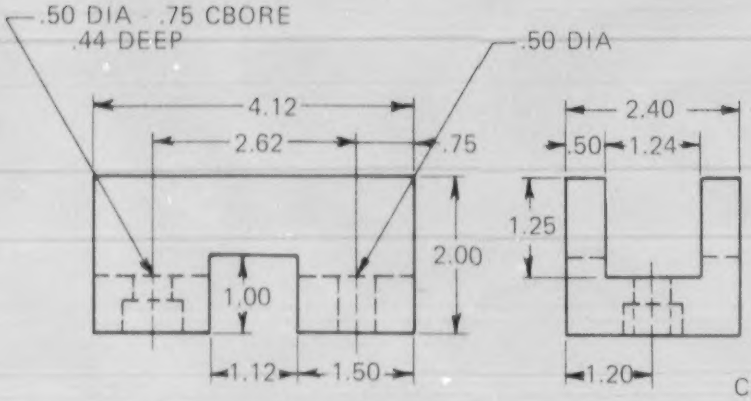
(NOTE: Your instructor may wish to assign an alternate problem.)

A.


.76
1.00
.62
1.06
1.00
2.12
.56
1.12
2.50
1.60
30
2.76
2.62
4.80

LOCATOR

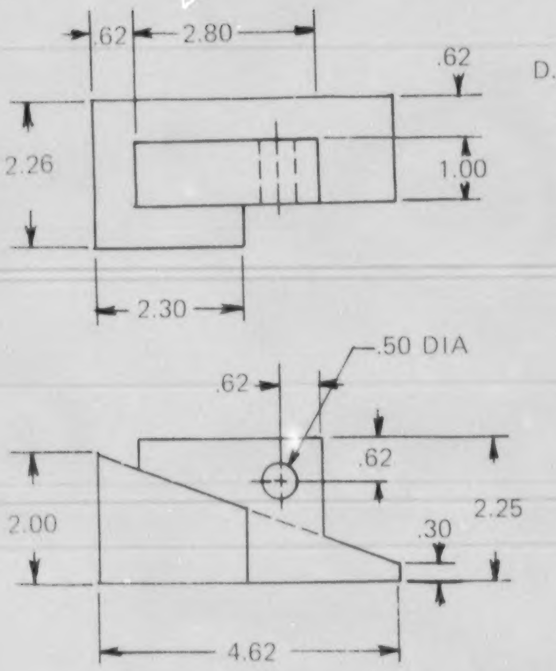
B.


.50 DIA - .75 CBORE
.44 DEEP
.50 DIA
4.12
2.62
.75
2.00
1.00
1.12
1.50
2.40
.50
1.24
1.25
1.20

CENTER BRACKET

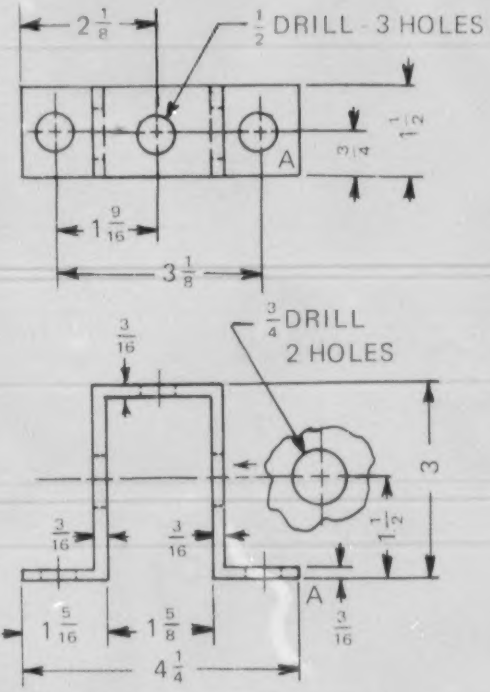
ASSIGNMENT SHEET #1

C.


.62
2.80
.62
2.26
1.00
2.30
.50 DIA
.62
.62
2.00
2.25
.30
4.62

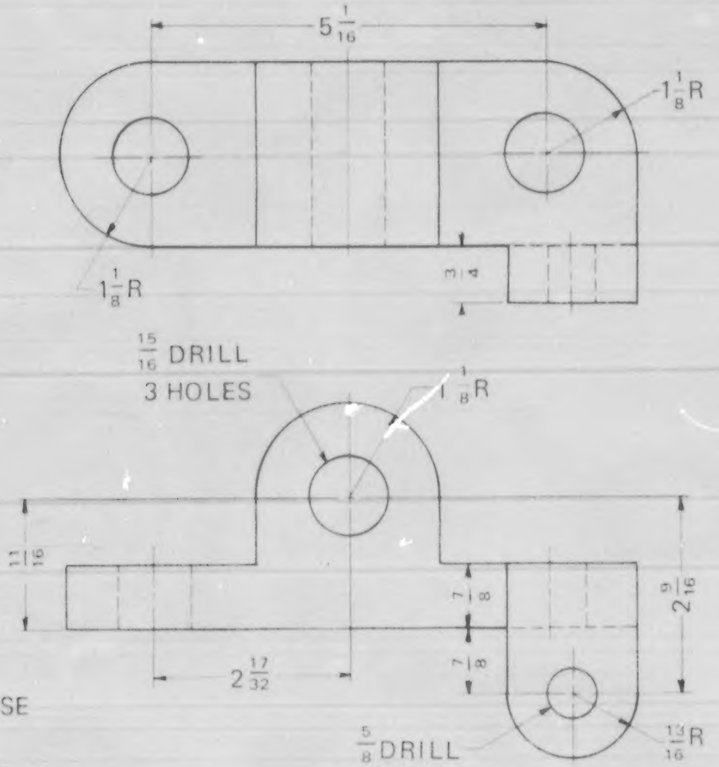
SLIDE

D.


2 1/8
1/2 DRILL - 3 HOLES
3/4
1 1/2
A
1 9/16
3 1/8
3/16
3/4 DRILL
2 HOLES
3
3/16
3/16
1 1/2
A
3/16
1 5/16
1 5/8
4 1/4

GEAR SUPPORT

E.


5 1/16
1 1/8 R
1 1/8 R
3/4
15/16 DRILL
3 HOLES
1 1/8 R
11/16
7/8
7/8
2 9/16
2 17/32
5/8 DRILL
13/16 R

BASE

PRESENTATION DRAWINGS
UNIT VII

ASSIGNMENT SHEET #2-CONSTRUCT CONCEPTUAL PRESENTATION SKETCHES

Directions: On "A" size vellum or other media selected by instructor, construct conceptual sketches of one of the problems below to include the following: 1) applicable dimensions and notes, 2) parts identification, and 3) shape description.

Problems:

(NOTE: Your instructor may wish to assign an alternate problem.)

A. Design safety or security devices for fire or theft to help save lives and prevent injury

B. Design a new or improved educational aid for your instructor

C. Design an improvement in vehicle transportation or racing

D. Design a home improvement product

PRESENTATION DRAWINGS
UNIT VII

ASSIGNMENT SHEET #3 CONSTRUCT DESIGN SKETCHES

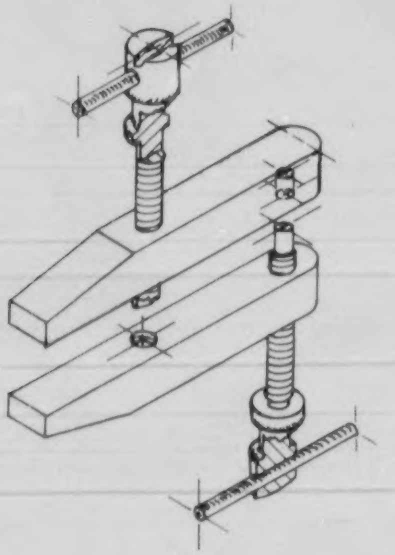
Directions: Using two sheets of "A" size vellum or other media selected by instructor, construct design sketches of two parts for one of the problems below or a problem from Assignment Sheet #2 to include the following: 1) shape description such as multiview and/or pictorial, 2) estimated size dimensions and notes, and 3) estimated material specifications.

(NOTE: Make sketches complete enough so a drafter can make detailed drawings.)

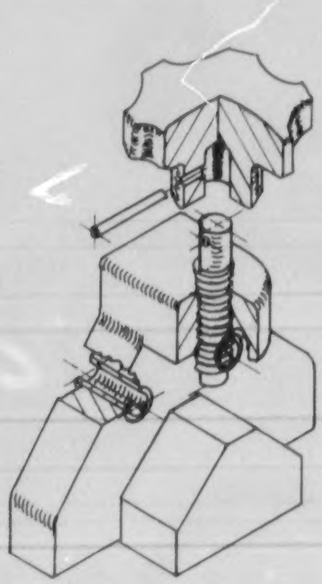
Problems:

(NOTE: Your instructor may wish to assign an alternate problem.)

A.



B.



PRESENTATION DRAWINGS
UNIT VII

ASSIGNMENT SHEET #4--CONSTRUCT A DIMETRIC PRESENTATION DRAWING

Directions: On "B" size vellum or other media selected by instructor, construct a dimetric drawing of one of the problems from Assignment Sheet #1 to appropriate scale using pencil or ink. You will need to select your own dimetric axis. Make two quality blueline prints, and shade each dimetric print with a **different** type of shading. Shade original dimetric with **best** shading, and turn in blueline prints and original to instructor.

(NOTE: Your instructor may wish to assign an alternate problem.)

PRESENTATION DRAWINGS
UNIT VII

ASSIGNMENT SHEET #5--CONSTRUCT AN OBLIQUE PRESENTATION DRAWING

Directions: On "B" size vellum or other media selected by instructor, construct an oblique drawing of one of the problems from Assignment Sheet #1 to appropriate scale using pencil or ink. You will need to select your type of oblique such as cavalier, cabinet, or general. Make two quality blueline prints of your oblique, and shade oblique prints with **different** types of shading. Shade original with **best** shading, and turn in blueline prints and original to instructor.

(NOTE: Your instructor may wish to assign an alternate problem.)

PRESENTATION DRAWINGS
UNIT VII

ASSIGNMENT SHEET #6–CONSTRUCT A TWO POINT PRESENTATION PERSPECTIVE OF AN OBJECT

Directions: On "B" size vellum or other media selected by instructor, construct a two point perspective of one of the problems from Assignment Sheet #1 to appropriate scale using pencil or ink. You will need to select your own vanishing and station points. Make two quality blueline prints, and shade each perspective print with a **different** type of shading. Shade original with **best** shading, and turn in blueline prints and original to instructor.

(NOTE: Your instructor may wish to assign an alternate problem.)

PRESENTATION DRAWINGS
UNIT VII

ASSIGNMENT SHEET #7--CONSTRUCT AN EXPLODED ASSEMBLY PRESENTATION DRAWING

Directions: On "D" size vellum or other media selected by instructor, construct an exploded assembly drawing of a problem assigned by instructor to scale using pencil or ink as instructed to include the following: 1) selected shading, 2) parts identifications, 3) parts list, and 4) flow lines. You will need to select appropriate scale and the type of pictorial (axonometric, oblique, or perspective) you wish to draw. Make a blueline print of your completed drawing, and turn in blueline print and original to instructor.

(NOTE: You may be divided into teams to work on a large problem.)

PRESENTATION DRAWINGS
UNIT VII

NAME ______________________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. Simple exterior embellishments utilizing light effects to enhance the pictorial qualities of an object

_____b. Sketch, mechanical drawing, or rendering designed to illustrate a technical subject and help sell or clarify its idea to a client

_____c. Freehand drawing of technical ideas without instruments

_____d. Carefully drawn sketches prepared to be given to someone else to make detail drawings

_____e. Drawing showing all parts in relationship with each other and how they fit together

_____f. Recording and communicating technical ideas that are in the process of development

_____g. Three dimensional drawing in axonometric, oblique, or perspective to imitate a picture of an object

_____h. A simplified drafting technique to reduce drafting time that combines photographs and line drawing on a standard sheet layout

_____i. A simplified drafting technique in which drawing segments are pasted or typed in position on a drawing form and photographically reproduced

_____j. Drawing an invention in pictorial and explanatory form to convey the correct interpretation

_____k. A method of touching up photographs and adding shading to line drawings by blowing ink or paint pigments through an air cap onto the drawing

_____l. To reduce a drawing proportionally using a ratio

1. Freehand technical sketching
2. Photodrafting
3. Conceptual sketches
4. Reduction ratios
5. Design sketches
6. Presentation sketch or drawing
7. Airbrushing
8. Pictorial drawing
9. Shading
10. Paste-up drafting
11. Exploded assembly drawing
12. Patent drafting

2. Name three types of presentation sketches.

a. ______________________________

b. ______________________________

c. ______________________________

3. Arrange in order the following steps of sketching by placing the correct sequence numbers in the appropriate blanks.

______a. Block in object proportionately with light construction lines

______b. Clean up unnecessary construction lines with an eraser and darken final visible lines

______c. Sketch light construction of an enclosing box or cylinder in proportion

4. Select true statements concerning ellipse construction by placing an "X" in the appropriate blanks.

______a. On horizontal plane, major axis is horizontal

______b. On right side plane, major axis is 60° from horizontal

______c. On left side plane, major axis is 45° from horizontal

______d. Diameter of circle is boxed in, and ellipse is sketched

______e. 45° bisector of each side of box is found and drawn mechanically with straight edge and compass

5. List three places where presentation drawings are found.

a. ______________________________

b. ______________________________

c. ______________________________

6. Complete the following list of shading techniques for presentation drawings.

a. Smudge

b. Transfer sheets

c. Shadows

d. ______________________________

e. ______________________________

f. ______________________________

7. Distinguish between the types of axonometric drawings by placing an "I" next to the characteristics of isometric, a "D" next to the characteristic of dimetric, and a "T" next to the characteristic of trimetric.

   _____ a. 120° between axes

   _____ b. All angles are unequal

   _____ c. All axes are at different angles

   _____ d. Two angles are equal

   _____ e. All angles are equal

   _____ f. Width and height full scale

   _____ g. Width, height, and depth are unequal

8. Select true statements concerning oblique drawings by placing an "X" in the appropriate blanks.

   _____ a. Cabinet obliques are drawn half scale on the depth axis

   _____ b. General obliques can be drawn full scale on the depth axis or other scales

   _____ c. Cavalier obliques are drawn half scale on the depth axis

9. Match the parts of exploded assembly presentation drawings on the right with the correct uses.

   _____ a. Used to differentiate one part from another

   _____ b. Should be on same sheet directly above title block

   _____ c. Used if tied to parts list

   _____ d. Can be duplicated and pasted up on drawing to save time

   _____ e. Indicate where parts fit

   _____ f. Lines in front take precedence over lines in back by gapping back lines for front lines

   _____ g. Used if immediate identification is important

   _____ h. Should be in natural position rather than just to fit the paper

   1. Numbers
   2. Part names
   3. Flow lines
   4. Shading
   5. Standard hardware
   6. Axis
   7. Parts list
   8. Overlapping parts

10. Select special requirements for patent drawings by placing an "X" in the appropriate blanks.

______a. Draw mechanically correct to help understand the invention

______b. Dimension and detail as working drawings

______c. Illustrate each claim

______d. Use center lines and notes

______e. Use poster paper 4" by 5"

______f. Line shade and surface shade to improve readability

______g. Draw in pencil so changes can be made

11. Demonstrate the ability to:

a. Shade pictorials.

b. Construct conceptual presentation sketches.

c. Construct design sketches.

d. Construct a dimetric presentation drawing.

e. Construct an oblique presentation drawing.

f. Construct a two point presentation perspective of an object.

g. Construct an exploded assembly presentation drawing.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

PRESENTATION DRAWINGS
UNIT VII

ANSWERS TO TEST

1. a. 9
   b. 6
   c. 1
   d. 5
   e. 11
   f. 3
   g. 8
   h. 2
   i. 10
   j. 12
   k. 7
   l. 4

2. a. Conceptual
   b. Design
   c. Presentation

3. a. 2
   b. 3
   c. 1

4. a, b, d

5. Any three of the following:
   a. Catalogs
   b. Sales literature
   c. Proposals
   d. Technical reports
   e. Patents
   f. Parts books

6. d. Lines
   e. Dots-stippling
   f. Air brush

7. a. I
   b. T
   c. T
   d. D
   e. I
   f. D
   g. T

8. a, b

9. a. 4
   b. 7
   c. 1
   d. 5
   e. 3
   f. 8
   g. 2
   h. 6

10. a, c, f

11. Evaluated to the satisfaction of the instructor

MATERIALS AND SPECIFICATIONS
UNIT VIII

UNIT OBJECTIVE

After completion of this unit, the student should be able to specify materials and write specifications for working drawings to include materials, heat treatment, and standard shapes. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to materials and specifications with the correct definitions.
2. List specifications sometimes found on mechanical drawings.
3. Match general heat treatments for metals with the correct definitions.
4. Match surface hardening treatments for metals with the correct definitions.
5. Select forms of carbon steel.
6. Complete a list of categories of pipe based on end use.
7. List three specifications for tubing callouts.
8. Match structural steel shapes with the correct specifications.
9. List standard mill forms of materials.
10. Match metal properties with the correct definitions.
11. List factors to consider in selecting materials.
12. Distinguish between physical and manufacturing characteristics of metals.
13. Complete a list of types and kinds of ferrous manufacturing metals.
14. Identify parts of the steel numbering system.
15. Select primary copper type metals.
16. Match the designations of condition of aluminum with the correct definitions.
17. Distinguish between advantages and disadvantages of aluminum.
18. Distinguish between advantages and disadvantages of zinc.

19. Distinguish between types of plastic materials.

20. Distinguish between advantages and disadvantages of plastics.

21. Match refractory materials with the correct uses.

22. Demonstrate the ability to:

    a. Determine wire and sheet metal size from gage number.

    b. Select materials from a materials stock book.

MATERIALS AND SPECIFICATIONS
UNIT VIII

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and assignment sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Have students look through ASM's *Metals Handbook* and SME's *Tool and Manufacturing Handbook* to see the full depth of this subject.

VII. Take a field trip to a smelter, foundry, or other metal producing plant.

VIII. Take a field trip to a metal fabricator to observe stock materials in the as received condition.

IX. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

   A. Objective sheet

   B. Information sheet

   C. Transparency masters

      1. TM 1--Metal Properties

      2. TM 2--Steel Numbering System

      3. TM 3--Aluminum Alloy Numbering System

      4. TM 4--Aluminum Classification System

   D. Test

   E. Answers to test

II. References:

   A. *Metals Handbook.* American Society for Metals, Metals Park, Ohio. 1980.

   B. *Tool and Manufacturing Handbook.* 3rd ed. Society of Manufacturing Engineers. New York: McGraw-Hill Book Co., 1976.

C. *Materials Selector Guide*, 1980.

D. Chaplin, Jack W. *Metal Manufacturing.* Bloomington, IL: McKnight Publishing Co., 1976.

E. *Modern Plastics Encyclopedia.* New York: McGraw-Hill Book Co., 1967.

F. The Society of the Plastics Industry, *Plastics Engineering.* New York: Reinhold Publishing Corp., 1960.

G. *Shapes and Plates,* United States Steel, Pittsburgh, Pennsylvania 15230.

H. *Metals Stock List,* Ducommun Metals Company, P. O. Box 82356, 2101 South Villa, Oklahoma City, OK 73108.

I. *Ryerson Data Book,* Joseph T. Ryerson & Son, Inc., Box 8000-A, Chicago, IL 60680.

J. *Patterson Steel Company Reference Book,* Metal Service Center, 801 North Xanthus, P. O. Box 2620, Tulsa, OK 74101.

K. *Steel Sales Stock List,* Steel Sales Corp., 3348 S. Pulaski Rd., Chicago, IL 60623.

L. *Steel and Aluminum Stock List and Reference Book,* #76, Earle M. Jorgensen Co., P. O. Box 16065, Denver, Colorado 80216.

MATERIALS AND SPECIFICATIONS
UNIT VIII

INFORMATION SHEET

I. Terms and definitions

   A. Toughness--Ability of a metal to resist rough treatment

   B. Ductility--Ability of a metal to stretch and flow under pressure without breaking

   C. Machinability--Relative difficulty of machining a metal

   D. Ferrous metals--Metals primarily composed of iron

   E. Nonferrous metals--Metals not composed of iron

   F. Organic material--Substance containing animal, vegetable, or carbon

      Example: Leather and wood

   G. Inorganic materials--Substance not containing animal, vegetable, or carbon

      Example: Cement, glass, and graphite

   H. AISI (American Iron and Steel Institute)--Issues steel specifications for steel-working industry

   I. ASME (American Society of Mechanical Engineers)--Issues steel plate specifications

   J. ASTM (American Society for Testing and Materials)--Writes specifications for all materials

   K. ANSI (American National Standards Institute)--Coordinates standards development and resolves standards problems for the United States

   L. SAE (Society of Automotive Engineers)--Issues steel bar specifications

   M. UNS--Unified National Standard for metals

   N. Materials classification system--Standard designation system by AISI, SAE, ASTM, ASME, or UNS

   O. Heat treatment--Operation or combined operations of heating a metal and cooling it to obtain certain specifications

   P. Thermosetting--Plastic which permanently hardens (sets) after heating

   Q. Thermoplastic--Plastic which repeatedly softens with heat

INFORMATION SHEET

II. Specifications sometimes found on mechanical drawings

A. Material

B. Finish

C. General tolerances

D. Color

E. Heat treatment

F. Number required

G. Hardness

H. Weight

I. Manufacturing process or operation

(NOTE: Specifications may be required depending on the organizational structure of the manufacturing department.)

III. General heat treatments for metals and definitions

A. Annealing--To soften metal and release stresses

B. Hardening--To harden metal by dipping in oil, water, air, or brine

C. Tempering--To reduce internal stresses

D. Surface hardening--To harden surface while leaving inside soft

IV. Surface hardening treatments for metals and definitions

A. Carburizing--Introduction of carbon to surface

B. Cyaniding--Introduction of carbon and nitrogen to surface

C. Nitriding--Introduction of nitrogen to surface

D. Induction hardening--Electrical heating of surface before quench

E. Flame hardening--Flame heating of surface before quench

V. Forms of carbon steel

A. Cold-rolled sheets

(NOTE: These are available in commercial quality for bending, forming, and welding, and in drawing quality for severe forming or drawing.)

INFORMATION SHEET

B. Plates

1. Rectangles

2. Coils

   (NOTE: Coils are rarely used due to the difficulty of flattening the plate for processing.)

C. Bars

1. Hot-rolled

   (NOTE: These are rounds, squares, flats, half rounds, and half ovals, and are available in merchant quality and special quality.)

2. Cold-rolled

   (NOTE: These are rounds, hexagons, squares, and flats.)

VI Categories of pipe based on end use

A. Pressure pipe

B. Structural and mechanical pipe

C. Standard pipe

VII Specifications for tubing callouts

A. Outside diameter

B. Inside diameter

C. Wall thickness

VIII Structural steel shapes and specifications

A. Beams, columns, and channels--Depth of the section and by weight

B. Angles--Length of legs and weight per foot

C. Tees--Width of flange, overall depth of stem, and weight per foot

D. Zees--Depth of section, flange width, and weight per foot

E. Wide-flange sections--Depth of section, flange width, and weight per foot

INFORMATION SHEET

IX. Standard mill forms of materials

- A. Foil (.0002" to .0055" thick, 7" to 36" wide)
- B. Strip (1/16" thick, 1/4" to 12" wide)
- C. Sheet (18 gage [.0478] to 7 gage [.1793], 24" to 72" wide)
- D. Plates (3/16 to 12" thick, 9" to 120" wide)
- E. Bar (1/4 to 6" square, 1/4 to 4" hexagon, up to 12' length)
- F. Rod (7/32 to 4 7/16 diameter)
- G. Wire (.004 to .625 diameter)
- H. Tubing (1/32 to 24 OD, .004" to 3" thick walls)
- I. Angle (Legs 1/2" to 9", up to 80 ft. long)
- J. Channel (Depth 3" to 18", 4.1#/foot to 42.7#/Foot, 20'-60' long)
- K. I Beam (Depth 3" to 24", 5.7#/foot to 100#/foot, 20' to 60' long)
- L. Expanded sheet (36 gage to 22 gage, up to 72" by 144")
- M. Perforated sheet (24 gage, to 14 gage up to 48" x 120")
- N. Coils (.001 to .1793 thick general use--1/4, 1/2 coiled for special material handling equipment--6"-60" wide)

  (NOTE: Refer to a materials selector guide for reference to finished stock sizes. Standard mill sizes indicated in parentheses are for general reference only and to give you a feeling for material size and shape.)

X. Metal properties and definitions (Transparency 1)

- A. Tensile strength--Maximum load divided by cross sectional area just before straining when tensile loading a specimen
- B. Compressive strength--Maximum stress that a material can withstand during compression just before deformation
- C. Torsional strength--Maximum load in twisting action just before deformation
- D. Modulus of elasticity--Measure of the rigidity of a metal; ratio of stress to the strain

INFORMATION SHEET

E. Shear strength--Stress required to produce a fracture across a plane perpendicular to the cross section, the direction of forces and resistance being opposite and parallel with the paths offset a small amount

F. Bend strength--Maximum stress at which fracture occurs during bending

(NOTE: This is also known as modulus of rupture.)

XI. Factors to consider in selecting materials

A. Costs

1. Per ton
2. Per pound
3. Per piece
4. Per unit of strength

(NOTE: You want to select materials with the lowest cost and the highest number of desirable characteristics.)

B. Strength

C. Rigidity

D. Space filling

E. Surface finish

F. Manufacturability

G. Machinability

H. Weldability

I. Weight

J. Corrosion resistance

XII. Characteristics of metals

A. Physical characteristics

1. Toughness (shock loading)
2. Rigidity (resist forces)
3. Loading (weight - stress)
4. Strength (great forces)
5. Ductility (can be drawn or rolled without breaking)

INFORMATION SHEET

B. Manufacturing characteristics

1. Machinability (ease or difficulty for chip removal)
2. Formability (ease of plastic flow)
3. Joinability (ease of joining by welding, adhesives, or mechanical fasteners)
4. Castability (formed into parts)

XIII. Types and kinds of ferrous manufacturing metals

A. Cast iron

1. Gray cast iron
2. White cast iron
3. Malleable iron
4. Ductile (nodular) iron
5. Alloy cast iron

B. Carbon steel

1. Low carbon steel--.05% to .30% carbon (mild steel)
2. Medium carbon steel--.30% to .60% carbon
3. High carbon steel--.60% to 1.5% carbon

C. Alloy steel

1. Low alloy steel
2. Medium alloy steel

XIV. Parts of the steel numbering system (Transparency 2)

A. Classification body

B. Process

C. Approximate alloying element

D. Carbon content

Example: .4% carbon = 40

INFORMATION SHEET

XV. Primary copper type metals

- A. Copper
- B. Brass
- C. Leaded brass
- D. Phosphor bronze
- E. Aluminum bronze
- F. Silicon bronze
- G. Beryllium
- H. Cupro nickel
- I. Nickel silver

XVI. Designations of condition of aluminum (Transparencies 3 and 4)

- A. F--Fabricated
- B. O--Annealed
- C. H--Strain hardened
- D. W--Solution treated
- E. T (T3-T10)--Special conditions

XVII. Advantages and disadvantages of aluminum

- A. Advantages
    1. Corrosion resistance
    2. Electrical and thermal conductivity
    3. Attractive appearance
    4. Light compared to steel, brass, nickel, or copper
    5. Load carrying capacities based on equal weight of material compares very favorably with steel
    6. Ease of fabrication
    7. Non-sparking and non-magnetic

INFORMATION SHEET

B. Disadvantages

1. Loses part of strength at elevated temperatures
2. Galvanic corrosion possible when in contact with other metals
3. Alkalis are corrosive to aluminum
4. Lower mechanical properties than those of steel when of equal cross section (not weight)

XVIII. Advantages and disadvantages of zinc

A. Advantages

1. Easier to cast than aluminum because of lower melting point

   (NOTE: Zinc is used in the automotive industry and general manufacturing because it is so easy to cast.)

2. Low cost
3. High production rate
4. Resistance to atmospheric corrosion
5. Ability to provide galvanic protection to steel

B. Disadvantages

1. Two to three times heavier than aluminum in equivalent die castings
2. Not as dimensionally stable as aluminum castings
3. Toxic--Cannot be used for food packaging

XIX. Types of plastic materials

(NOTE: Only more common plastics are listed.)

A. Thermosetting (reheating will not soften)

1. Epoxides--Esters and straight epoxies

   (NOTE: These are used for fastening, molding, casting, laminating, potting (encasing of electronic parts), and manufacturing press dies for metal forming.)

2. Amino resins--Urea and Melamine--formaldehyde

   (NOTE: These are used in tableware, knobs, and electrical appliances.)

INFORMATION SHEET

3. Phonolics

   (NOTE: These are used in missiles, dials, and electrical parts.)

4. Polyesters

   (NOTE: These are used in skylights, sports car bodies, and aircraft parts.)

B. Thermoplastics (may be reheated to soften)

1. Acrylonitrite-butadiene-styrena--ABS

   (NOTE: This is used in tool handles and automotive parts.)

2. Acetals--Copolymer and homopolymer

   (NOTE: These are used in plumbing valves, pumps, faucets, toys, gears, and cams.)

3. Acrylic resin--Methyl methacrylate

   (NOTE: This is used for outdoor signs, sunscreens, windows, and canopies.)

4. Polyethylene--Also known as polythene

   (NOTE: This is used for packaging material, bottles, and insulation.)

5. Polycarbonate

   (NOTE: This is used for safety glass, housings, and electrical appliances.)

6. Polyethylene resins

   (NOTE: These are used for garden hose, toys, ice trays, and packaging.)

7. Polypropylene

   (NOTE: This is used for textiles, furniture, and toys.)

8. Celluloses--Acetate, acetate-butyrate, ethyl-cellulose

   (NOTE: These are used for knobs, toys, and extruded tubes.)

9. Polystyrenes

   (NOTE: These are used for tumblers, toys, and housings.)

10. Polysulfones

    (NOTE: These are used for switch gears and appliances.)

INFORMATION SHEET

11. Vinyl resins--Polyvinyl butyrate, polyvinyl chloride (PVC), polyvinylidene chloride, and cellular-vinyl

    (NOTE: These are used in safety glass, raincoats, pipe, and floats.)

12. Synthetic rubber

    (NOTE: This is used in tires, hose, shoe soles, and shock absorbing pads.)

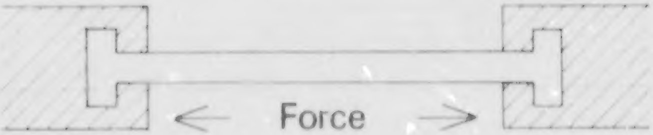
XX. Advantages and disadvantages of plastics

- A. Advantages
    1. Often outlast metal equivalent parts at reasonable speed and load
    2. Often outlast metals in corrosive environments
    3. Dampen shock vibration and noise
    4. Can operate with little or no lubricant
    5. Machine easier and faster
- B. Disadvantages
    1. Are more dimensionally sensitive to temperature changes
    2. Cannot be produced to as high precision tolerance as most metals
    3. Have lower load carrying capacity

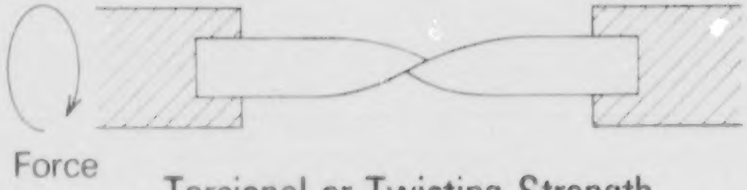
XXI. Refractories

- A. Concrete--Structures
- B. Glass--Windows
- C. Aluminum--Rocket nozzles and furnace parts
- D. Graphite--Heat shields for re-entry vehicles
- E. Ceramics--Normal and high temperatures

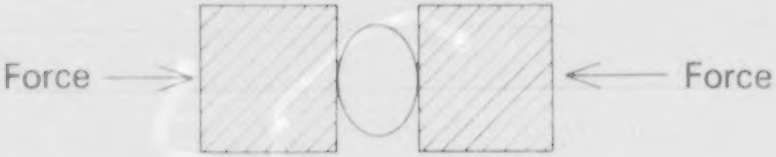
Metal Properties



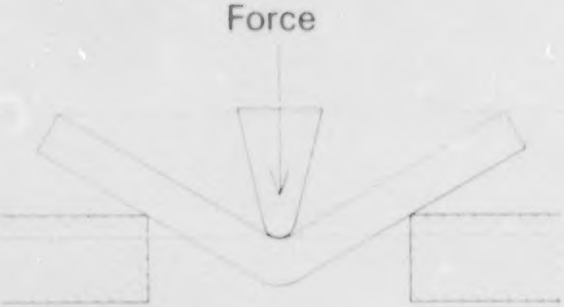
Tensile Strength



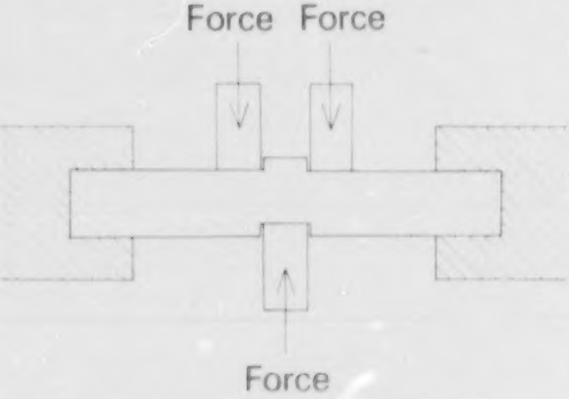
Torsional or Twisting Strength


Force
Force

Compressive Strength



Bend Strength


Force
Force
Force

Shear Strength

Steel Numbering System

Classification Body
- * AISI
- * SAE
- UNS
- ASTM
- ASME

* Most Used

Steel Manufacturing Process (Optional)

B - Bessemer Steel
C - Open Hearth Steel
D - Electric Furnace Steel

AISI C 13 40 0

UNS Only

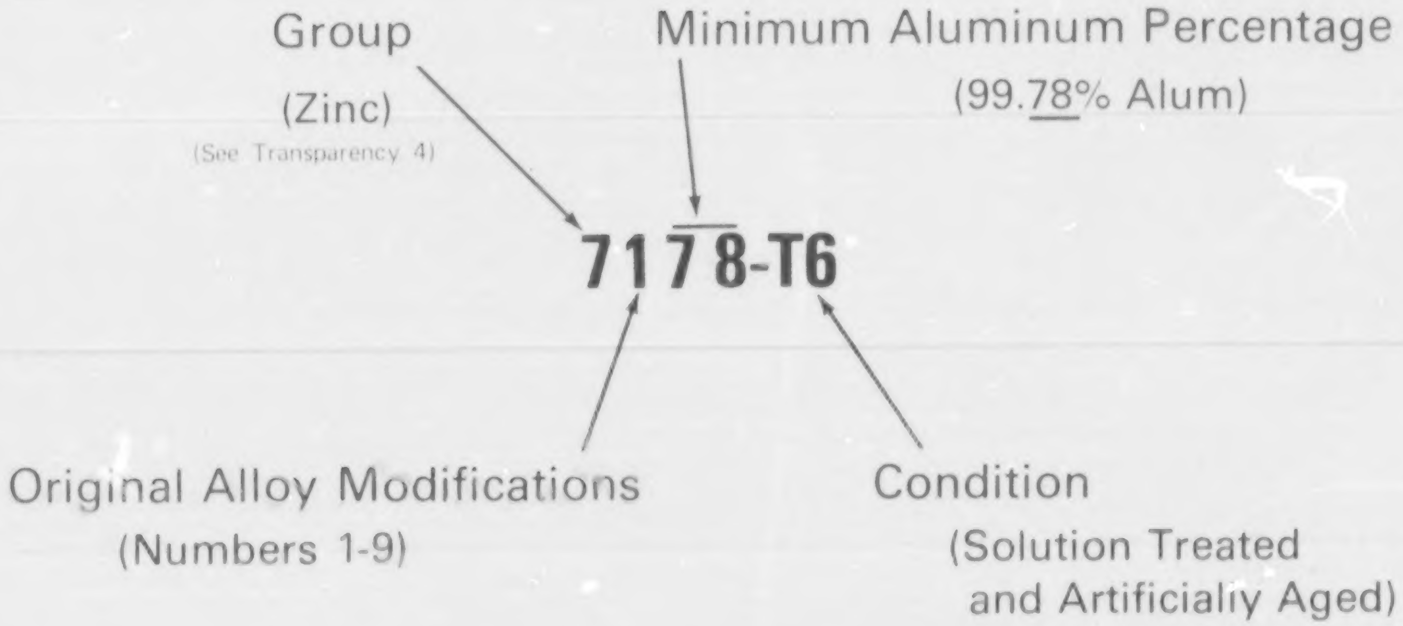
Approximate Percentage of Main Alloying Element

10XX - Plain Carbon
11XX - Lead-Free Machining Steel
13XX - Manganese
2XXX - Nickel
3XXX - Nickel and Chromium
4XXX - Molybdenum
5XXX - Chromium
6XXX - Chromium-Vanadium
7XXX - Tungsten
8XXX - Nickel-Chromium-Molybdenum
9XXX - Manganese-Silicon

Carbon Content (Hundredths of One Percent)

.4% Carbon

Aluminum Alloy Numbering System



Group

(Zinc)

(See Transparency 4)

Minimum Aluminum Percentage

(99.$\underline{78}$% Alum)

$71\overline{7}8$-T6

Original Alloy Modifications

(Numbers 1-9)

Condition

(Solution Treated
and Artificially Aged)

TM 3

MD - 597

Aluminum Classification System

(Modifiers)

1XXX	Aluminum
2XXX	Copper
3XXX	Manganese
4XXX	Silicon
5XXX	Magnesium
6XXX	Magnesium and Silicon
7XXX	Zinc
8XXX	Other Elements
9XXX	Unused Series

MATERIALS AND SPECIFICATIONS
UNIT VIII

ASSIGNMENT SHEET #1--DETERMINE WIRE AND SHEET METAL SIZE FROM GAGE NUMBER

Directions: Using the standard wire and sheet gage charts included with this assignment sheet, determine wire and sheet metal size from gage number. The following example can be used as a guideline.

Example: Find the size of a Birmingham wire #0000 gage

1. Go to standard wire gage chart attached
2. Read down "Gage No." column until 4-0's is reached; the 4-0's means 0000
3. Read across Birmingham column to where it intersects 4-0's column
4. Answer is .454

Problems:

A. Find the size of a Birmingham wire #9 gage

____

B. Find the size of a steel manufacturers' sheet #23 gage

____

C. Find the size of a Brown and Sharpe for nonferrous metals wire #36 gage

____

D. Find the size of an American S and W Co.'s std steel wire #36 gage

____

ASSIGNMENT SHEET #1

STANDARD WIRE & SHEET GAGES

WIRE GAGES
Decimal Inch Equivalent

SHEET GAGES

GAGE No.	BIRMINGHAM[1] WIRE GAGE (BWG) (Stubs Iron Gauge)	STEEL[2] WIRE GAGE (Washburn & Moen)	AMERICAN[3] WIRE GAGE (Brown & Sharpe)	STEEL SHEETS Thickness in Inches	ALUMINUM SHEETS Thickness in Inches	STAINLESS STEEL SHEETS Approx. Thickness in Inches	GALVANIZED SHEETS Thickness in Inches
40		.0070	.00314				
39		.0075	.00353				
38		.0080	.00396	.0060	.00396		
37		.0085	.00445	.0064	.00445		
36	.004	.0090	.00500	.0067	.00500		
35	.005	.0095	.00561	.0075	.00561		
34	.007	.0104	.00630	.0082	.00630		
33	.008	.0118	.00708	.0090	.00708		
32	.009	.0128	.00795	.0097	.00795	.010	.0134
31	.010	.0132	.00893	.0105	.00893	.011	.0142
30	.012	.0140	.0100	.0120	.0100	.013	.0157
29	.013	.0150	.0113	.0135	.0113	.014	.0172
28	.014	.0162	.0126	.0149	.0126	.016	.0187
27	.016	.0173	.0142	.0164	.0142	.017	.0202
26	.018	.0181	.0159	.0179	.0159	.019	.0217
25	.020	.0204	.0179	.0209	.0179	.022	.0247
24	.022	.0230	.0201	.0239	.0201	.025	.0276
23	.025	.0258	.0226	.0269	.0226	.028	.0306
22	.028	.0286	.0253	.0299	.0253	.031	.0336
21	.032	.0317	.0285	.0329	.0285	.034	.0366
20	.035	.0348	.0320	.0359	.0320	.038	.0396
19	.042	.0410	.0359	.0418	.0359	.044	.0456
18	.049	.0475	.0403	.0478	.0403	.050	.0516
17	.058	.0540	.0453	.0538	.0453	.056	.0575
16	.065	.0625	.0508	.0598	.0508	.063	.0635
15	.072	.0720	.0571	.0673	.0571	.070	.0710
14	.083	.0800	.0641	.0747	.0641	.078	.0785
13	.095	.0915	.0720	.0897	.0720	.094	.0934
12	.109	.1055	.0808	.1046	.0808	.109	.1084
11	.120	.1205	.0907	.1196	.0907	.125	.1233
10	.134	.1350	.1019	.1345	.1019	.141	.1382
9	.148	.1483	.1144	.1495	.1144	.156	.1532
8	.165	.1620	.1285	.1644	.1285	.172	.1681
7	.180	.1770	.1443	.1793	.1443		
6	.203	.1920	.1620	.1943	.1620		
5	.220	.2070	.1819	.2092	.1819		
4	.238	.2253	.2043	.2242	.2043		
3	.259	.2437	.2294	.2391	.2294		
2	.284	.2625	.2576				
1	.300	.2830	.2893				
0	.340	.3065	.3249				
2-0's	.380	.3310	.3648				
3-0's	.425	.3625	.4096				
4-0's	.454	.3938	.4600				
5-0's	.500	.4305	.5165				
6-0's		.4615	.5800				
7-0's		.4900					

1. Used for tubing wall thicknesses and certain strip and spring steel products
2. Used by virtually all manufacturers of *steel* wire in U.S.
3. Used for copper, brass, aluminum, and other nonferrous metals
4. Aluminum sheets use the same gage numbers as American Wire gage--order aluminum by thickness not gaye

MATERIALS AND SPECIFICATIONS
UNIT VIII

ASSIGNMENT SHEET #2--SELECT MATERIALS FROM A MATERIALS STOCK BOOK

Directions: Using the *Steel and Aluminum Stock List and Reference Book* or any comparable materials stock book, solve the problems which follow for selecting materials. The following example can be used as a guideline.

Example: Select the standard sheet size length and width for 14 gage hot-rolled steel sheet ASTM A570, Grade A to fit a design 57" by 143". Consider the least amount of wasted material in your selection. Also find the estimated weight per sheet.

1. Go to standard materials stock book
2. Read index of stock book for steel sheets
3. Locate ASTM A570, Grade A Hot Rolled Flat sheets
4. Locate 14 gage thickness
5. Locate sheet size a 57" by 143" would fit
6. Answer is 60" by 144"
7. Estimate of lbs. per sheet is 187.5#

Problems:

A. Select the standard purchased sheet size length and width for 22 gage cold rolled commercial quality ASTM A366 steel sheet to fit a design 31" by 97". Consider the least amount of wasted material in your selection. Also find the estimated weight per sheet.

1. Sheet size length and width ______________________________
2. Estimated weight per sheet ______________________________

B. Select the standard purchased sheet size length and width for .063 thick .5052 aluminum flat sheets Spec QQ A250/8 with 1+32 mill finish to fit a design 45" by 85". Consider the least amount of wasted materials in your selection. Also find weight per sheet.

1. Sheet size length and width ______________________________
2. Estimated weight per sheet ______________________________

ASSIGNMENT SHEET #2

C. Select the standard purchased sheet size length and width for .032 thick zinc alloy sheets QQ-Z100A to fit a design 29" x 115". Consider the least amount of wasted materials in your selection. Also find weight per sheet.

1. Sheet size length and width ________________

2. Estimated weight per sheet ________________

D. Select the standard purchased estimated weight per foot 1018 hexagon cold finished bar ASTM A108 of 11/16 inches across flats. Also find the stock length

1. Estimated weight per foot ________________

2. Stock length ________________

E. Select a bar size angle ASTM A36 to fit a design need of 2 1/2" by 2" by 5/16 thick. What is the estimated weight per foot, and what lengths are available?

1. Estimated weight per foot ________________

2. Lengths available ________________

F. Select a wide flange structural beam ASTM A36 with a depth of 18.12", flange width 7.532" and web thickness of .390". Find the AISI designation and estimated weight per foot.

1. AISI designation ________________

2. Estimated weight per foot ________________

G. Select a carbon steel tubing--round seamless mechanical tubing cold drawn outside diameter (OD) 2 7/8 and inside diameter 2.125". Find the wall thickness and estimated weight per foot.

1. Wall thickness ________________

2. Estimated weight per foot ________________

MATERIALS AND SPECIFICATIONS
UNIT VIII

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. .148
B. .0269
C. .00500
D. .0090

Assignment Sheet #2

(NOTE: Answers may vary slightly according to the stock book used.)

A. 1. 36" by 120"
   2. 37.5 #
B. 1. 48" by 96"
   2. 28.06 #
C. 1. 36" by 120"
   2. 36 #
D. 1. 1.39 #
   2. 10' to 12'
E. 1. 4.50 #
   2. 20', 30', 40'
F. 1. W18 x 55
   2. 55.0 #
G. 1. .375"
   2. 10.01 #

MATERIALS AND SPECIFICATIONS
UNIT VIII

NAME ______________________________

TEST

1. Match the terms on the right with the correct definitions.

______ a. Ability of a metal to resist rough treatment

______ b. Ability of a metal to stretch and flow under pressure without breaking

______ c. Relative difficulty of machining a metal

______ d. Metals primarily composed of iron

______ e. Metals not composed of iron

______ f. Substance containing animal, vegetable, or carbon

______ g. Substance not containing animal, vegetable, or carbon

______ h. Issues steel specifications for steel-working industry

______ i. Issues steel plate specifications

______ j. Writes specifications for all materials

______ k. Coordinates standards development and resolves standards problems for the United States

______ l. Issues steel bar specifications

______ m. Unified National Standard for metals

______ n. Standard designation system by AISI, SAE, ASTM, ASME, or UNS

______ o. Operation or combined operations of heating a metal and cooling it to obtain certain specifications

______ p. A plastic which permanently hardens after heating

______ q. Plastic which repeatedly softens with heat

1. SAE
2. Machinability
3. AISI
4. Organic material
5. Thermosetting
6. ANSI
7. Ductility
8. Nonferrous metals
9. Heat treatment
10. Toughness
11. Thermoplastic
12. UNS
13. Ferrous metals
14. Inorganic material
15. ASME
16. ASTM
17. Materials classification system

2. List four specifications sometimes found on mechanical drawings.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

3. Match general heat treatments for metals on the right with the correct definitions.

   ______a. To soften metal and release stresses

   ______b. To harden metal by dipping in oil, water, air, or brine

   ______c. To reduce internal stresses

   ______d. To harden surface while leaving inside soft

   1. Tempering
   2. Annealing
   3. Surface hardening
   4. Hardening

4. Match surface hardening treatments for metals on the right with the correct definitions.

   ______a. Introduction of carbon to surface

   ______b. Introduction of carbon and nitrogen to surface

   ______c . Introduction of nitrogen to surface

   ______d. Electrical heating of surface before quench

   ______e. Flame heating of surface before quench

   1. Induction hardening
   2. Carburizing
   3. Cyaniding
   4. Flame hardening
   5. Nitriding

5. Select forms of carbon steel by placing an "X" in the appropriate blanks.

   ______a. Warm-rolled sheets

   ______b. Coil plates

   ______c. Hot-rolled bars

   ______d. Rectangle particles

   ______e. Liquid

   ______f. Cold-rolled bars

6. Complete the following list of categories of pipe based on end use.

   a. Pressure pipe

   b. Structural and mechanical pipe

   c. ______________________________

7. List three specifications for tubing callouts.

a. ______________________________

b. ______________________________

c. ______________________________

8. Match structural steel shapes on the right with the correct specifications.

______a. Depth of the section and by weight

______b. Length of legs and weight per foot

______c. Width of flange, overall depth of stem, and weight per foot

______d. Depth of section, flange width, and weight per foot

1. Angles
2. Beams, columns, and channels
3. Wide-flange sections and Zees
4. Tees

9. List five standard mill forms of materials.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

10. Match the metal properties on the right with the correct definitions.

______a. Maximum load in twisting action just before deformation

______b. Maximum stress at which fracture occurs during bending

______c. Maximum stress that a material can withstand during compression just before deformation

______d. Maximum load divided by cross sectional area just before straining when tensile loading a specimen

______e. Measure of the rigidity of a metal; ratio of stress to the strain

______f. Stress required to produce a fracture across a plane perpendicular to the cross section, the direction of forces and resistance being opposite and parallel with the paths offset a small amount

1. Tensile strength
2. Compressive strength
3. Torsional strength
4. Modulus of elasticity
5. Shear strength
6. Bend strength

11. List six factors to consider in selecting materials.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

12. Distinguish between physical and manufacturing characteristics of metals by placing an "X" next to the physical characteristics.

______[illegible] Strength

______b. Castability

______c. Rigidity

______d. Ductility

______e. Machinability

______f. Toughness

______g. Formability

13. Complete the following list of types and kinds of ferrous manufacturing metals.

a. Cast iron

    1) ____________________

    2) ____________________

b. ____________________

    1) ____________________

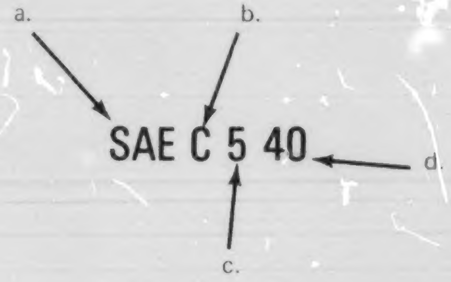
    2) Low carbon steel

c. Alloy steel

    1) ____________________

    2) ____________________

14. Identify the parts of the steel numbering system.



a. ______________________ b. ______________________

c. ______________________ d. ______________________

15. Select primary copper type metals by placing an "X" in the appropriate blanks.

_____a. Zinc

_____b. Leaded brass

_____c. Beryllium

_____d. Cupro nickel

_____e. Cast iron

_____f. Nickel silver

_____g. Silicon bronze

16. Match the designations of condition of aluminum on the right with the correct definitions.

_____a. Solution treated	1. F
_____b. Annealed	2. O
_____c. Special conditions	3. H
_____d. Fabricated	4. W
_____e. Strain hardened	5. T

17. Distinguish between advantages and disadvantages of aluminum by placing an "X" next to the advantages.

______a. Alkalis are corrosive to aluminim

______b. Electrical and thermal conductivity

______c. Ease of fabrication

______d. Loses part of strength at elevated temperatures

______e. Light compared to steel

______f. Non-sparking and non-magnetic

18. Distinguish between advantages and disadvantages of zinc by placing an "X" next to the advantages.

______a. High production rate

______b. Toxic--Cannot be used for food packaging

______c. Easier to cast than aluminum because of a lower melting point

______d. Resistance to atmospheric corrosion

______e. Two to three times heavier than aluminum in equivalent die castings

19. Distinguish between types of plastic materials by placing an "X" next to the thermosetting plastics and an "O" next to the thermoplastics.

______a. Polyethylene

______b. Amino resins

______c. Acrylic

______d. Vinyl resins

______e. Polyesters

______f. Polypropylene

______g. Epoxides

______h. Acetals

20. Distinguish between advantages and disadvantages of plastics by placing an "X" next to the advantages.

______a. Are more dimensionally sensitive to temperature changes

______b. Machine easier and faster

______c. Often outlast metals in corrosive environments

______d. Have lower load carrying capacity

______e. Dampen shock vibration and noise

21. Match the refractory materials on the right with the correct uses.

______a. Heat shields for re-entry vehicles	1. Concrete
______b. Windows	2. Glass
______c. Rocket nozzles and furnace parts	3. Aluminum
______d. Normal and high temperatures	4. Graphite
______e. Structures	5. Ceramics

22. Demonstrate the ability to:

   a. Determine wire and sheet metal size from gage number.

   b. Select materials from a materials stock book.

   (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

MATERIALS AND SPECIFICATIONS
UNIT VIII

ANSWERS TO TEST

1.	a.	10	f.	4	k.	6	p.	5
	b.	7	g.	14	l.	1	q.	11
	c.	2	h.	3	m.	12		
	d.	13	i.	15	n.	17		
	e.	8	j.	16	o.	9		

2. Any four of the following:
   a. Material
   b. Finish
   c. General tolerances
   d. Color
   e. Heat treatment
   f. Number required
   g. Hardness
   h. Weight
   i. Manufacturing process or operation

3. a. 2
   b. 4
   c. 1
   d. 3

4. a. 2
   b. 3
   c. 5
   d. 1
   e. 4

5. b, c, f

6. c. Standard pipe

7. a. Outside diameter
   b. Inside diameter
   c. Wall thickness

8. a. 2
   b. 1
   c. 4
   d. 3

9. Any five of the following:
   a. Foil
   b. Strip
   c. Sheet
   d. Plates
   e. Bar
   f. Rod
   g. Wire
   h. Tubing
   i. Angle
   j. Channel
   k. I beam
   l. Expanded sheet
   m. Perforated sheet
   n. Coils

10. a. 3
    b. 6
    c. 2
    d. 1
    e. 4
    f. 5

11. Any six of the following:
    a. Costs
    b. Strength
    c. Rigidity
    d. Space filling
    e. Surface finish
    f. Manufacturability
    g. Machinability
    h. Weldability
    i. Weight
    j. Corrosion resistance

12. a, c, d, f

13. a. Any two of the following:
       1) Gray cast iron
       2) White cast iron
       3) Malleable iron
       4) Ductile iron
       5) Alloy cast iron
    b. Carbon steel
       Any one of the following:
       1) Medium carbon steel
       2) High carbon steel
    c. Any two of the following:
       1) Low alloy steel
       2) Medium alloy steel

14. a. Classification body
    b. Process
    c. Approximate alloying element
    d. Carbon content

15. b, c, d, f, g

16. a. 4
    b. 2
    c. 5
    d. 1
    e. 3

17. b, c, e, f

18. a, c, d

19. a. O
    b. X
    c. O
    d. O
    e. X
    f. O
    g. X
    n. O

20. b, c, e

21. a. 4
    b. 2
    c. 3
    d. 5
    e. 1

22. Evaluated to the satisfaction of the instructor

MANUFACTURING PROCESSES
UNIT IX

UNIT OBJECTIVE

After completion of this unit, the student should be able to design parts for manufacturing processes. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to manufacturing processes with the correct definitions.
2. State three purposes of manufacturing processes.
3. Identify principal types of drawings for manufacturing processes.
4. Match casting terms with the correct definitions.
5. Select true statements concerning design procedures for a casting.
6. Distinguish between pattern and machine dimensions.
7. Match forging terms with the correct definitions.
8. Select true statements concerning design procedures for a forging.
9. Match welding terms with the correct definitions.
10. Select true statements concerning design procedures for a welded assembly.
11. Match machines with the correct processes.
12. Name advantages of numerical control machinery.
13. Match plastic manufacture terms with the correct definitions.
14. Select true statements concerning methods of fabricating plastics.
15. Select true statements concerning design procedures for plastics.
16. Match sheet metal processing terms with the correct definitions.
17. Identify sheet metal hems and joints.
18. Calculate bend allowance for sheet metal.

19. Demonstrate the ability to:
    a. Design a casting part.
    b. Design a forging part.
    c. Design a welded part.
    d. Design a thermoplastic part.

MANUFACTURING PROCESSES
UNIT IX

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and assignment sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Tour several manufacturing plants such as welding, foundry, machine shop, or sheet metal plants, and explain the processes in use.

VII. Tour the welding shop, foundry, machine shop, or plastic shop in your school or school district, and ask the instructors to explain the processes in use. Discuss the differences and similarities between the school shops and the actual manufacturing plants.

VIII. Discuss the major difference between the types of drawings for various manufacturing processes.

IX. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

   A. Objective sheet

   B. Information sheet

   C. Transparency masters

      1. TM 1--Sand Casting Drawing
      2. TM 2--Machining Drawing
      3. TM 3--Welding Drawing
      4. TM 4--Sheet Metal Drawing
      5. TM 5--Forging Drawing
      6. TM 6--Sand Mold Pattern
      7. TM 7--Starting to Make the Sand Mold
      8. TM 8--After Rolling Over the Drag

9. TM 9--Preparing to Ram Molding Sand in Cope
10. TM 10--Complete Mold - Separated
11. TM 11--Completed Mold
12. TM 12 Design of Castings
13. TM 13--Design of Castings (Continued)
14. TM 14--Pattern and Machine Dimensions
15. TM 15--Sheet Metal Hems and Joints
16. TM 16--Bend Allowance

D. Assignment sheets

1. Assignment Sheet #1--Calculate Bend Allowance for Sheet Metal
2. Assignment Sheet #2--Design a Casting Part
3. Assignment Sheet #3--Design a Forging Part
4. Assignment Sheet #4--Design a Welded Part
5. Assignment Sheet #5--Design a Thermoplastic Part

E. Answers to assignment sheets

F. Test

G. Answers to test

II. References:

A. Johnson, Harold V. *Manufacturing Processes Metals and Plastics*. Peoria, IL 61614: Charles A. Bennett Co., Inc., 1973.

B. Amstead, B. H., P.F. Ostwald, and M.L. Begeman. *Manufacturing Processes*. New York: John Wiley and Sons, 1977.

C. Jensen, C.H. *Engineering Drawing and Design*. New York: Gregg Division/ McGraw-Hill Book Co., 1968.

D. *Tool and Manufacturing Handbook*, 3rd edition, Society of Manufacturing Engineers. New York: McGraw-Hill Book Co.,, 1976.

E. Blodgett, Omer W. *Design of Weldments*. The James F. Lincoln Arc Welding Foundation, Cleveland, OH, 1963.

F. Oberg, Erik, Franklin E. Jones, and Holbrook Horton. *Machinery's Handbook*. 20th ed. New York: Industrial Press, Inc., 1979.

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MANUFACTURING PROCESSES
UNIT IX

INFORMATION SHEET

I. Terms and definitions

A. Casting--Metal object formed by pouring molten metal into a mold until solidified

B. Pattern--Form used to make a cavity in sand mold

C. Core--Special body designed to produce a special cavity in or on a casting

D. Permanent mold casting--Casting produced with metal molds plus hydrostatic pressure

E. Die casting--Process of forcing hot metal into a metal mold or die

F. Centrifugal casting--Process of pouring metal into a revolving mold

G. Investment casting--"Lost wax" process of pouring a sand mixture (investment) around a wax pattern; the casting is made by pouring molten metal into the hardened sand shell melting and forcing the wax out

H. Shell molding--Process using thin sand resin shells molded of the pattern and molten metal is poured into the cavity

(NOTE: This process produces close tolerance parts.)

I. Hot working metal--Metal in plastic state formed by mechanical working

(NOTE: Mechanical workings include rolling and forging.)

J. Cold working metal--Forming or plastic deforming metals while metal is cold

K. Machining operations--To change the shape, finish, and size by removing material from the workpiece

L. Electroplating--Covering a metal by electro-deposits of a thin coating of the same or other metal

M. Chemical milling--Chemical removal of a metal from the workpiece

N. Flame spraying--Process of melting materials and blowing the melted metal on a surface

O. Laser machining--Precise removal of small amounts of metal by a concentrated focus of intense heat

P. Ultrasonic machining--Bombardment of a workpiece by grit driven by linear oscillation of the tool

INFORMATION SHEET

Q. Electron beam machining--Pulsing technique by accelerated electrons that heat and cool an area

R. Electronic discharge machining--Removal of metal by spark in the presence of a coolant

S. Electro-chemical machining--Reverse plating process of material removal

T. Chemical machining--Use of an acid to dissolve metal in areas except where acid resist is used

U. Numerical control (NC) machining--Operation of machine tools by automatic programmed cutting sequences using numerical data stored on paper, magnetic tape, tabulating cards, computer storage, or direct information to produce accurate machining of complex geometrical surfaces

V. Injection molding--Ramming of hot plastic into a mold

W. Fusion--The process of melting or melting together materials

X. Extrusion--The process of pushing (forcing) metal through a shape-formed die

Y. Surface preparation--A mechanical or chemical process to improve part appearance, surface hardness, coatability, and resistance to wear

Examples: Sand blasting, deburring, shot peening, electropolishing

Z. Computer numerical control (CNC) machining--A numerical control system using a special purpose computer to operate machine tools

AA. Automation--An NC machine or system of machines that control the sequence of operations, tool movement, or material movement with very little, if any, assistance from the operator

BB. Transfer machine--A machine that has the capability to transfer a workpiece from one operation to another operation within the machine or to another machine

(NOTE: Transfer machines permit the maximum number of production operations to be performed on workpieces at a maximum production rate.)

II. Purposes of manufacturing processes

A. Removing material from original part

B. Adding material to original part

C. Spreading material to other areas

INFORMATION SHEET

III. Principal types of drawings for manufacturing processes (Transparencies 1-5)

- A. Casting
- B. Machining
- C. Welding
- D. Sheet metal
- E. Forging

IV. Casting terms and definitions (Transparencies 6-11)

- A. Riser--Relief for air and molten metal to rise
- B. Flask--Complete mold
- C. Sprue--Tapered hole in the cope of a casting mold to pour molten metal into the mold cavity
- D. Parting line--Line of separation
- E. Draft--Pattern taper for easy removal of pattern from mold
- F. Drag--Bottom half of the flask
- G. Cope--Top half of the flask
- H. Cheek--Middle part of the flask
- I. Gate--Opening for the molten metal to flow between the sprue and the mold cavity
- J. Alignment pins--Devices to align drag and cope

V. Design procedures for a casting (Transparencies 12 and 13)

- A. Avoid abrupt changes in section
- B. Keep wall thickness of sections uniform
- C. Avoid internal stresses
- D. Use minimum number of adjoining sections
- E. Fillet radii should be equal to rib thicknesses
- F. Thicken thin members when they approach a thick member
- G. Odd number of spokes is better than even number to prevent stresses along opposite spokes
- H. Allow room for withdrawing of pattern from sand

INFORMATION SHEET

I. Use a shrink rule to lay out patterns

(NOTE: Each material has a different shrinkage factor. For example, a cast iron shrinkage rule is 1/8" longer per foot than a standard rule and an aluminum shrinkage rule is 5/32" longer per foot than a standard rule.)

J. A draft or taper must be added to the pattern to allow for removal from the mold

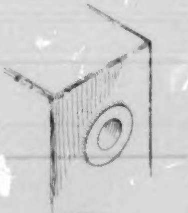
(NOTE: This is usually 1/8" to 1/4" per foot.)

K. A finish allowance or extra metal must be included for machining

(NOTE: This is normally 1/8" (3.2 mm) for small and average castings.)

L. Use a boss, a cylindrical projection on a casting, to give a bearing surface for a fastener

(NOTE: A boss requires less machining.)



BOSS

VI. Pattern and machine dimensions (Transparency 14)

A. Pattern dimensions--Dimensions needed only by a pattern maker to make a pattern

B. Machine dimensions--Dimensions needed only by a machinist to machine the part

VII. Forging terms and definitions

A. Parting line (flash line)--Line where dies meet and separate

B. Die closure--Added amount to the die when dies do not close

C. Parting plane--Plane perpendicular to the direction of pressure

D. Die--Device used in shaping or stamping an object or flat material

E. Flash--Slight excess thin fin of material surrounding a forging at the parting line

F. Draft--Taper of surfaces to allow easy removal from the die

G. Match tolerance--Measurement of displacement of two opposing dies in the direction parallel to the parting line of the dies

INFORMATION SHEET

VIII. Design procedures for a forging

A. Avoid sharp corner fillets

(NOTE: If material is flowing away, fillets may be sharper.)

B. Have large fillet if material is flowing toward fillet

C. Use strippers and ejectors when little or no draft is used

D. Allow generous tolerances for dies in areas of greatest pressure and flow

(NOTE: Generous tolerances in these areas will make dies last longer.)

IX. Welding terms and definitions

A. Arc welding--Most common process which uses electric arc to melt edges and melted electrode as additional material

B. Forge welding--Heated metal is forced together under pressure

C. Induction welding--Parts are heated by electric current to melt and fuse parts together

(NOTE: Induction welding is an economical mass production method.)

D. Resistance welding--A heavy current is passed through parts in contact which melts and fuses the parts together

E. Gas welding--Heating of metal by hot flame and melting of welding rod as a filler metal

F. Thermit welding--Chemical reaction between powdered aluminum and powdered metal oxide which causes them to be welded together

G. TIG--Gas tungsten inert shielding arc welding using a metal electrode

H. MIG--Gas metal inert shielding arc welding using a metal electrode

I. Plasma welding--An arc welding process in which the arc is constricted in a hot ionized gas flowing through an orifice

J. Nondestructive testing--A method of testing materials without impairing the usefulness of the material

Examples: Visual, magnetic particle, liquid penetrant, and X-ray

K. Destructive testing--A method of testing materials, usually samples, that destroys their usefulness

Examples: Chemical tests, hardness tests, mechanical tests, and notched bar impact test

INFORMATION SHEET

X. Design procedures for a welded assembly

   A. Use standard rolled shapes such as I beams, channels, zees, and tees

   B. Design for calculated load to avoid wasting materials

   C. Use deep sections to avoid bending

   D. Proper use of stiffeners will provide rigidity with less weight

   E. Use closed sections or diagonal bracing for torsion (twisting)

   F. Provide maintenance accessibility

   G. Design with minimum number of pieces

   H. Eliminate beveling if deep-penetrating arc can be used

   I. Use minimum root opening to avoid excess filler metal

   J. Place welds on shortest seams

XI. Machines and processes

   A. Turning machines--Cutting the workpiece by rotating the workpiece against the edge of the tool

   B. Milling machines--Cutting the workpiece by a rotating tool; the workpiece is then moved back into position for the next cut

   C. Drill press--Cutting circular holes in the workpiece by a rotating tool

   D. Shaper and planer--Cutting by tools going back and forth on workpiece while workpiece is automatically advanced

   E. Sawing machines--Making straight or circular cuts in a workpiece

   F. Broaching machines--Pulling or pushing a broaching tool over the workpiece surface to machine simple or complex contours

   (NOTE: Broaching is one of the most productive precision machining processes known to produce precision finishes, hold small tolerances, and eliminate the need for highly skilled machine operators.)

   G. Grinding machines--Removing tiny particles from the surface of the workpiece by abrasive action

XII. Advantages of numerical control machinery

   A. Greater control over the manufacturing process

   B. Higher cutting rates

   C. Large time savings

INFORMATION SHEET

D. Reduction of inventory

E. Fewer machines and operators required

F. Less skill required by operators

G. Reduced scrap and rework

H. Improved product design

XIII. Plastic manufacture terms and definitions

A. Thermoplastic welding--Fusing together of thermoplastic materials

B. Compression molding--Pressure and heat cause material to flow in a mold

C. Transfer molding--Plunger and high frequency preheating mold plastic in a mold cavity

D. Injection molding--Thermoplastic material is injected into a mold and cooled

E. Extrusion--Plastic is forced through die of the desired shape

F. Blow molding--Air is blown into heated plastic forcing it against the mold sides

G. Thermoforming--Preheating plastic sheets until limp, followed by vacuum forming over a mold

H. Rotational molding--Process in which plastisol plastic is fused while in a rotating mold

I. Laminating--Combination of materials by heat and pressure to form a single piece

XIV. Methods of fabricating plastics

A. Machining--Used on rigid plastics

B. Forming--Used on flexible thermoplastics

C. Welding--Used for joining rigid sheets of plastic

XV. Design procedures for plastics

A. Any wall or rib should be between a minimum of 3/32" to 5/32" thick

B. Any wall thickness should not exceed 1/8" thick

C. Draft or taper of 1° to 2° is desirable

D. Fillets should be added to facilitate molding with minimum distortion and breakage

INFORMATION SHEET

E. Ribs and bosses must have 5° tapers

F. Holes smaller than 1/16" in diameter must be drilled or formed after molding

(NOTE: These procedures are not exhaustive of the plastic industry. Please consult specific references for more details.)

XVI. Sheet metal processing terms and definitions

A. Metal spinning-Forming a sheet of metal over a mandrel while the sheet is rotating

B. Stretch forming--Stretching sheet metal and then forming by dies

C. High energy forming--Using high energy to shape metal such as explosive or magnetic forming

D. Shearing--Cutting metal by shearing action

E. Drawing--Stretching sheet over die in the form of the final product

F. Development--A pattern or shape in two dimensions for sheet metal

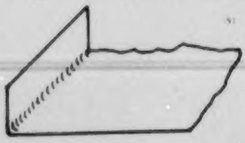
G. Bending--To form corners, edges, and seams in sheet metal

H. Bend relief holes--Holes drilled or punched at intersection of bends to relieve strain which would cause metal to crack or buckle

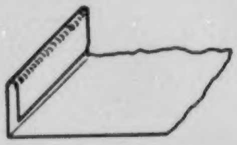
I. Spring back--An overbending operation to allow for the material to spring back into the desired shape

XVII. Sheet metal hems and joints (Transparency 15)

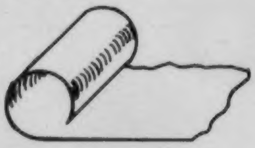
A. Single flange



B. Double flange

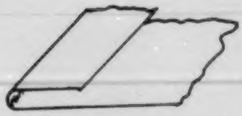


C. Rolled flange

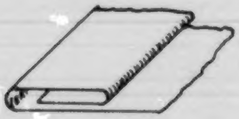


INFORMATION SHEET

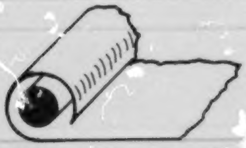
D. Single hem



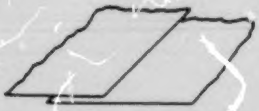
E. Double hem



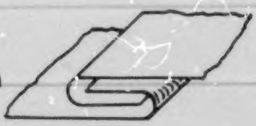
F. Wired edge



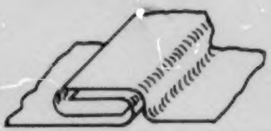
G. Lap seam



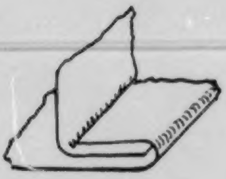
H. Plain flat seam



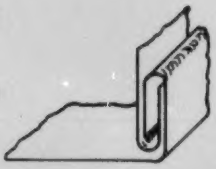
I. Grooved seam



J. Single seam

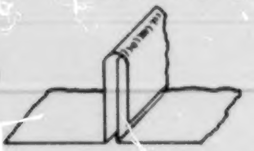


K. Double seam



INFORMATION SHEET

L. Standing seam



XVIII. Calculating bend allowance for sheet metal (Transparency 16)

A. BA = Bend allowance

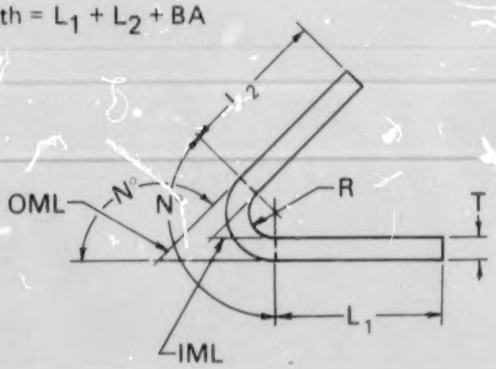
B. R = Radius of bend

C. T = Metal thickness

D. N = Number of degrees in bend

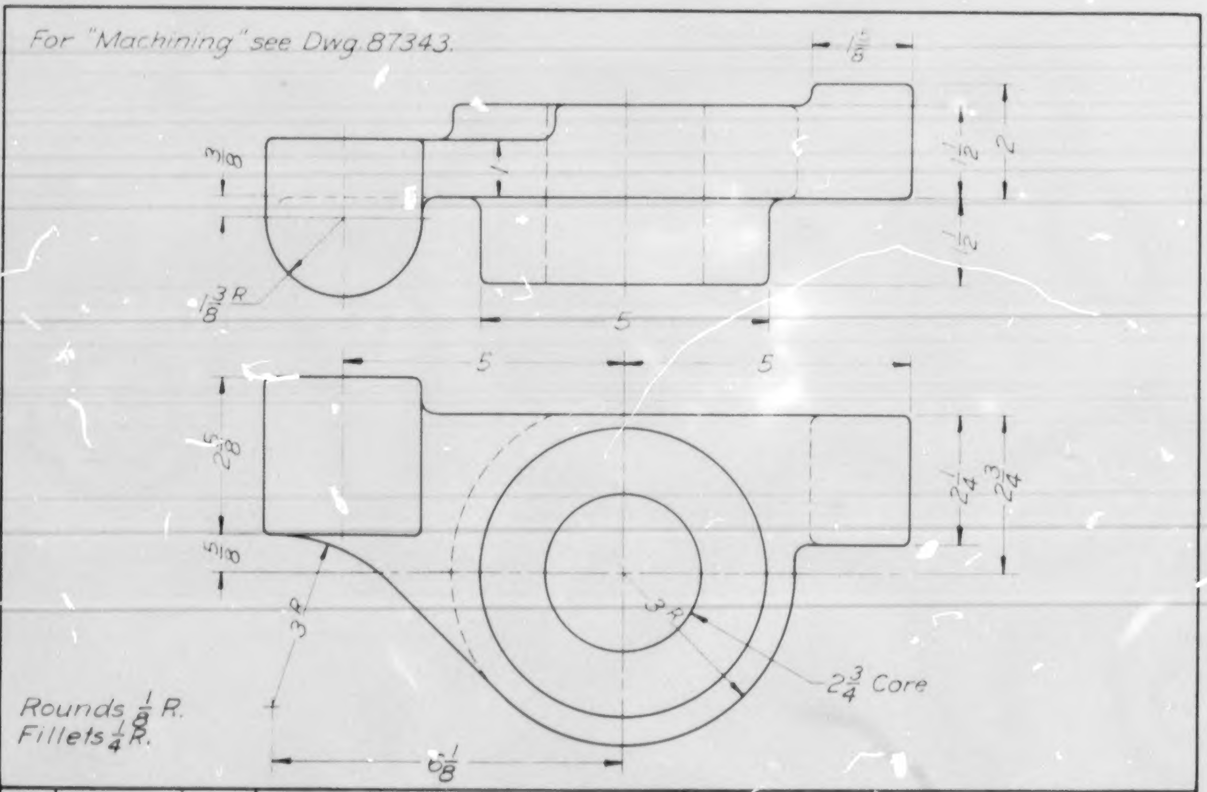
E. BA = (.01743R + .0078T)N

F. Length = $L_1 + L_2 + BA$



(NOTE: Bend allowance tables have been tabulated for many industries based on experimental data. As a rule of thumb BA equals 1/3 thickness for soft metals and 1/2 thickness for hard metals.)

Sand Casting Drawing



For "Machining" see Dwg 87343.

Rounds 1/8 R.
Fillets 1/4 R.

DWN	R.S.	6-7-77	LIMITS UNLESS OTHERWISE NOTED: FRACTIONAL ± 1/64. DECIMAL ± .010. ANGULAR ± 1/2°			REVISION	DATE	CHANGE OR ADDITION	
						MATERIAL	STOCK SIZE	HEAT TR	FINISH
TCD	R.S.	6-7-77	PART NO	REQD	NAME	C.I.			
CKD	L.K.D.	6-8-77	142-C	4	ROCKER ARM	SCALE	COMPANY NAME CITY		DRAWING NO.
APPD	James	6-10-77				1/2 Size			NO OF
	NAME	DATE	UNIT OR ASSEMBLY	MODEL 77 DIESEL		ASSY DR NO 87200			87342

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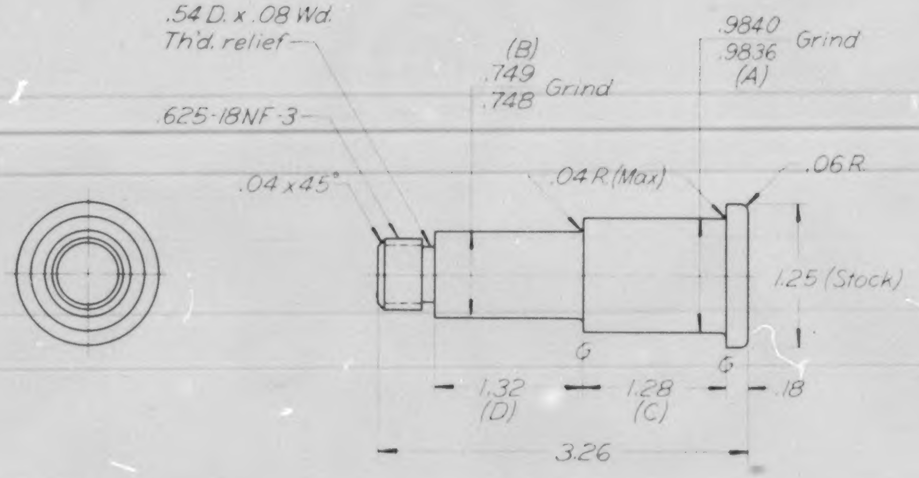
Machining Drawing


.54 D. x .08 Wd.
Th'd. relief
.625-18NF-3
.04 x 45°
(B)
.749
.748 Grind
.9840
.9836 Grind
(A)
.04 R (Max)
.06 R
1.25 (Stock)
G
G
1.32
(D)
1.28
(C)
.18
3.26

Heat-treatment:
1. Carburize at 1650° to 1700° F.
2. Quench direct.
3. Draw at 275°.
Protect threads during hardening.

DWN	C.K.K	1-3-77
TCD	JONES	1-7-77
CKD	I.L.S.	1-8-77
APPD	T.C.J.	1-8-77
	NAME	

LIMITS UNLESS OTHERWISE NOTED: ANGULAR ±½°
DECIMALS: THREE PLACE ±.010; TWO PLACE ±[illegible]

PART NO	REQD	NAME
103	1	STUD

UNIT OR ASSEMBLY: RAIL TRANSPORT HANGER

REVISION	DATE	CHANGE OR ADDITION

MATERIAL	STOCK SIZE	HEAT TR	FINISH
1020 C.R.	1.25 D x 3.3	Noted	Grind

SCALE: Full
ASSY DR NO: A 4755

COMPANY NAME
CITY

DRAWING NO
NO 1 OF 1
A-4762

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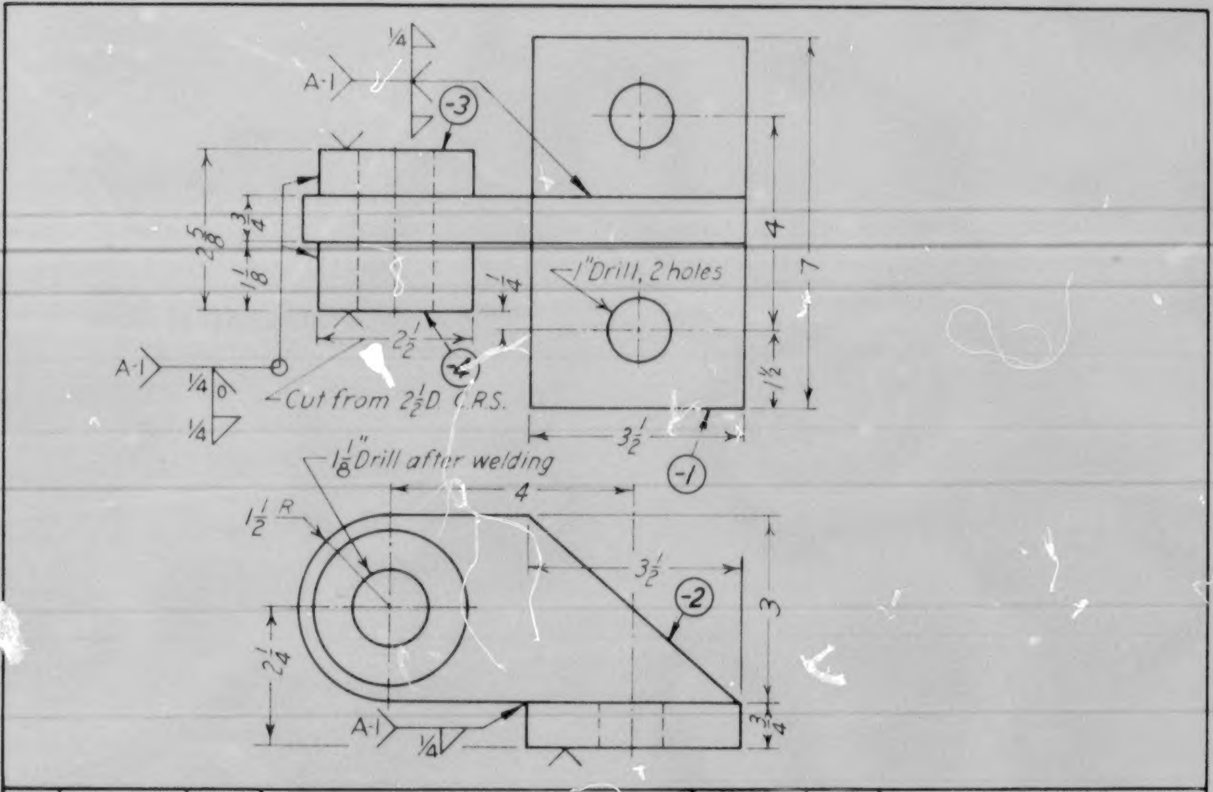
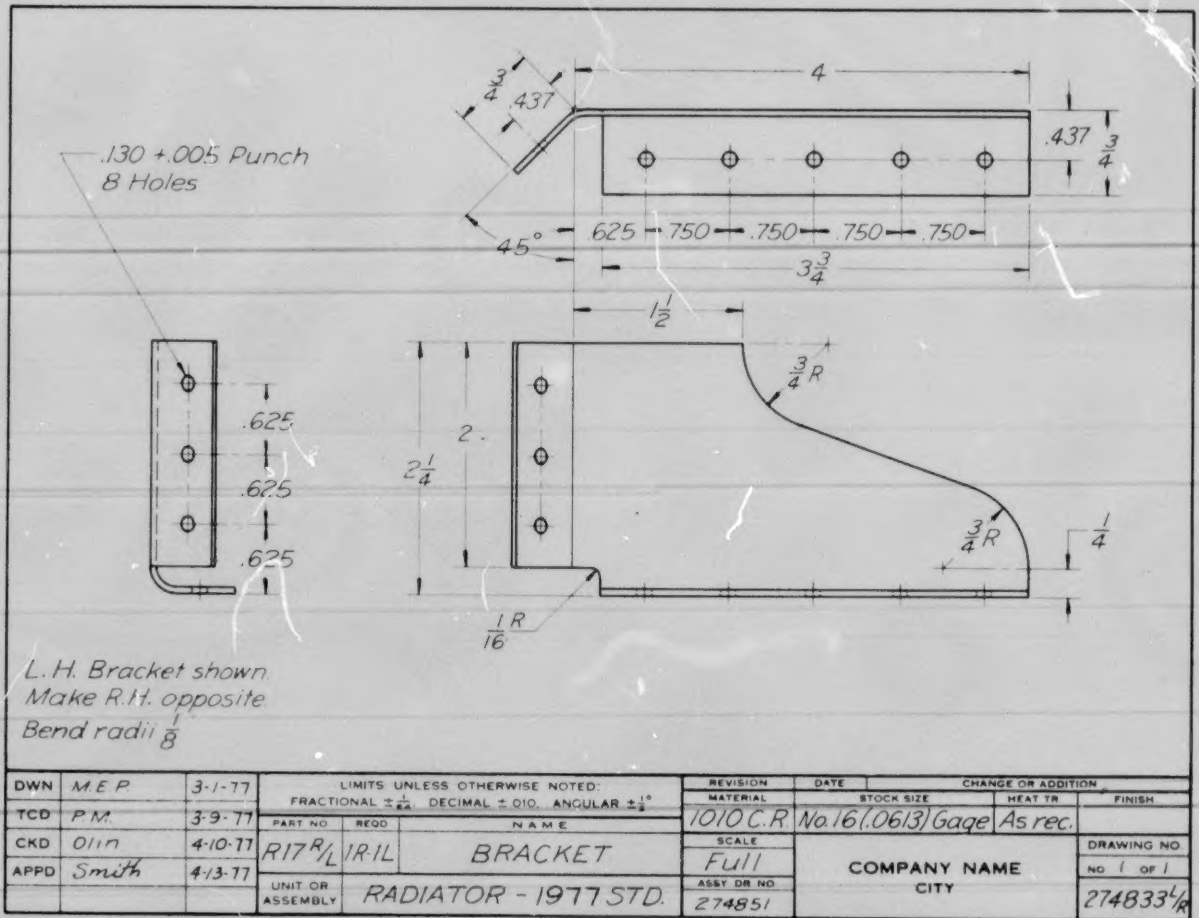
Welding Drawing


1/4
A-1
-3
2 5/8
3/4
1 1/8
1/4
2 1/2
-4
A-1
1/4
0
1/4
Cut from 2 1/2 D. C.R.S.
1" Drill, 2 holes
4
7
1 1/2
3 1/2
-1
1 1/8" Drill after welding
4
1 1/2 R
3 1/2
-2
3
2 1/4
3/4
A-1
1/4

DWN	G.M.	6-7-77	LIMITS UNLESS OTHERWISE NOTED FRACTIONAL ± 1/64 DECIMAL ± .010 ANGULAR ± 1/2°			REVISION	DATE	CHANGE OR ADDITION	
TCD	G.M.	6-7-77	PART NO	REQD	NAME	MATERIAL SAE 1020	STOCK SIZE	HEAT TR	FINISH
CKD	L.K.D.	6-8-77	137-B	4	BRACKET ASSY	SCALE 1/2 Size	COMPANY NAME CITY		DRAWING NO
APPD	James	6-10-77				ASSY DR NO			NO OF
	NAME	DATE	UNIT OR ASSEMBLY	DIESEL ASSY		93521			93624

Sheet Metal Drawing


4
3/4
.437
.437
3/4
.130 +.005 Punch
8 Holes
45°
.625
.750
.750
.750
.750
3 3/4
1 1/2
3/4 R
3/4 R
1/4
2
2 1/4
.625
.625
.625
1/16 R

L.H. Bracket shown.
Make R.H. opposite.
Bend radii 1/8

DWN	M.E.P.	3-1-77
TCD	P.M.	3-9-77
CKD	Olin	4-10-77
APPD	Smith	4-13-77

LIMITS UNLESS OTHERWISE NOTED:
FRACTIONAL ± 1/64. DECIMAL ± .010. ANGULAR ± 1/2°

PART NO	REQD	NAME
R17 R/L	1R-1L	BRACKET

UNIT OR ASSEMBLY: RADIATOR - 1977 STD.

REVISION	DATE	CHANGE OR ADDITION

MATERIAL	STOCK SIZE	HEAT TR	FINISH
1010 C.R.	No.16 (.0613) Gage	As rec.	

SCALE: Full
ASSY DR NO: 274851

COMPANY NAME
CITY

DRAWING NO
NO 1 OF 1
274833 L/R

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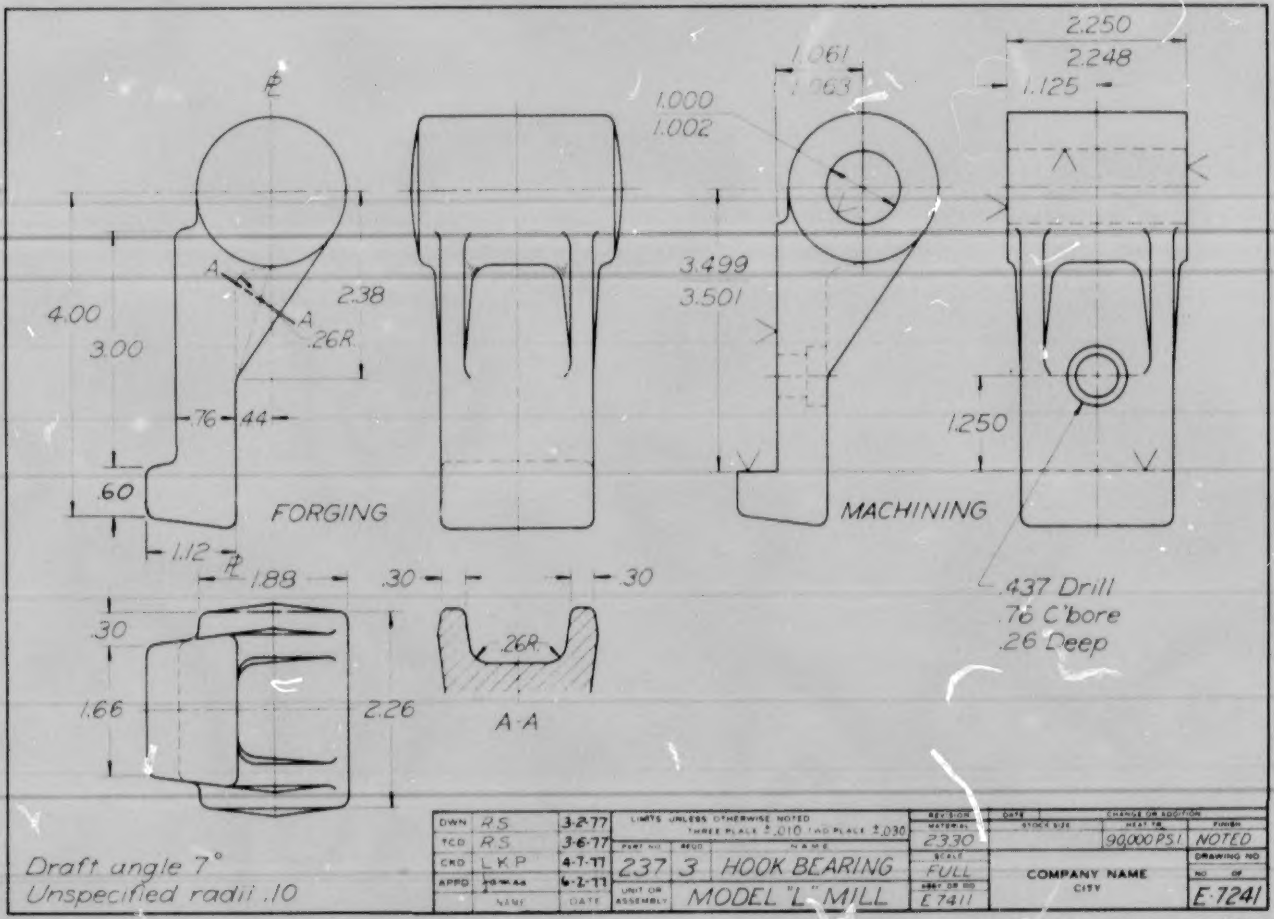
Forging Drawing


℄
4.00
3.00
2.38
.26R
A
A
.76
.44
.60
1.12
℄
FORGING
1.000
1.002
1.061
1.063
3.499
3.501
2.250
2.248
1.125
1.250
MACHINING
.437 Drill
.76 C'bore
.26 Deep
1.88
.30
.30
.30
1.66
2.26
.26R
A-A
Draft angle 7°
Unspecified radii .10
DWN R.S 3-2-77
TCD R.S 3-6-77
CKD LKP 4-7-77
APPD 6-2-77
NAME DATE
LIMITS UNLESS OTHERWISE NOTED
THREE PLACE ±.010 TWO PLACE ±.030
PART NO 237
REQD 3
NAME HOOK BEARING
UNIT OR ASSEMBLY MODEL "L" MILL
REVISION
DATE
CHANGE OR ADDITION
MATERIAL 2330
STOCK SIZE
HEAT TR. 90,000 PSI
FINISH NOTED
SCALE FULL
ASSY OR NO E 7411
COMPANY NAME
CITY
DRAWING NO
NO OF
E-7241

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Sand Mold Pattern

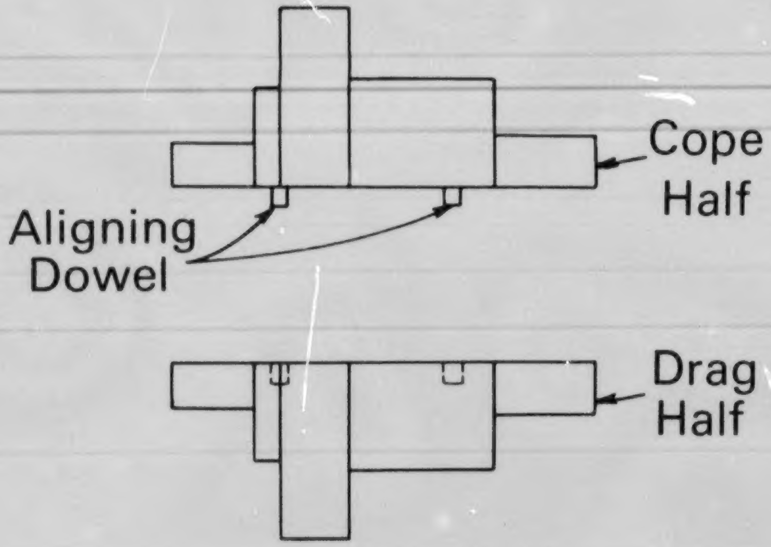

Cope
Half
Aligning
Dowel
Drag
Half

Fig. A

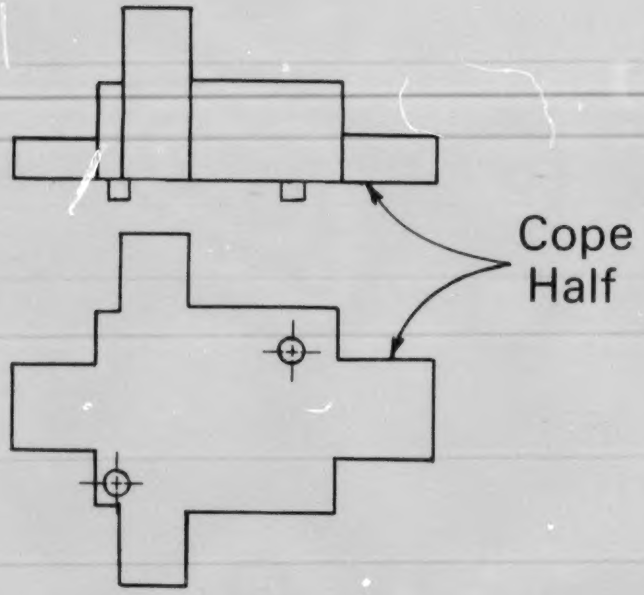
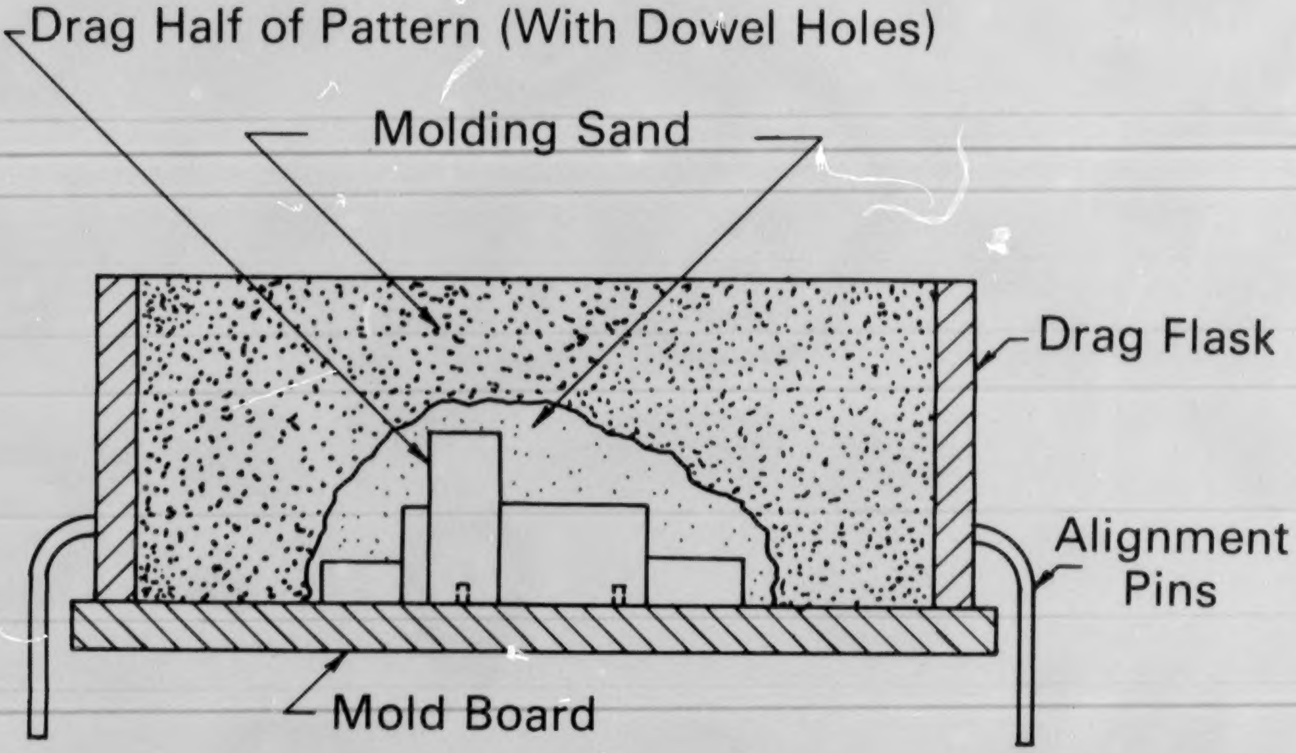


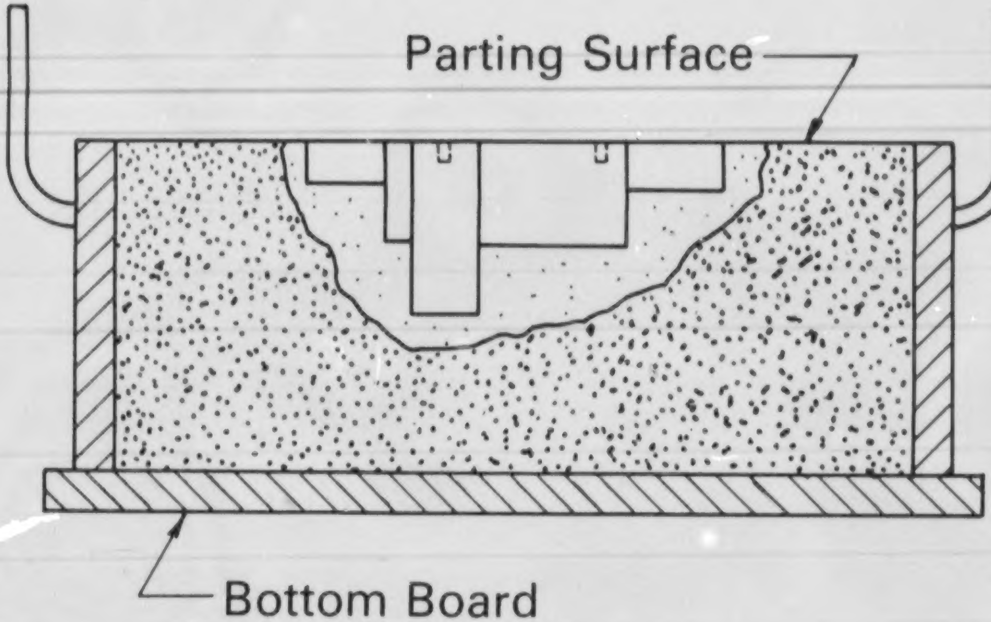
Fig. B

Starting to Make the Sand Mold

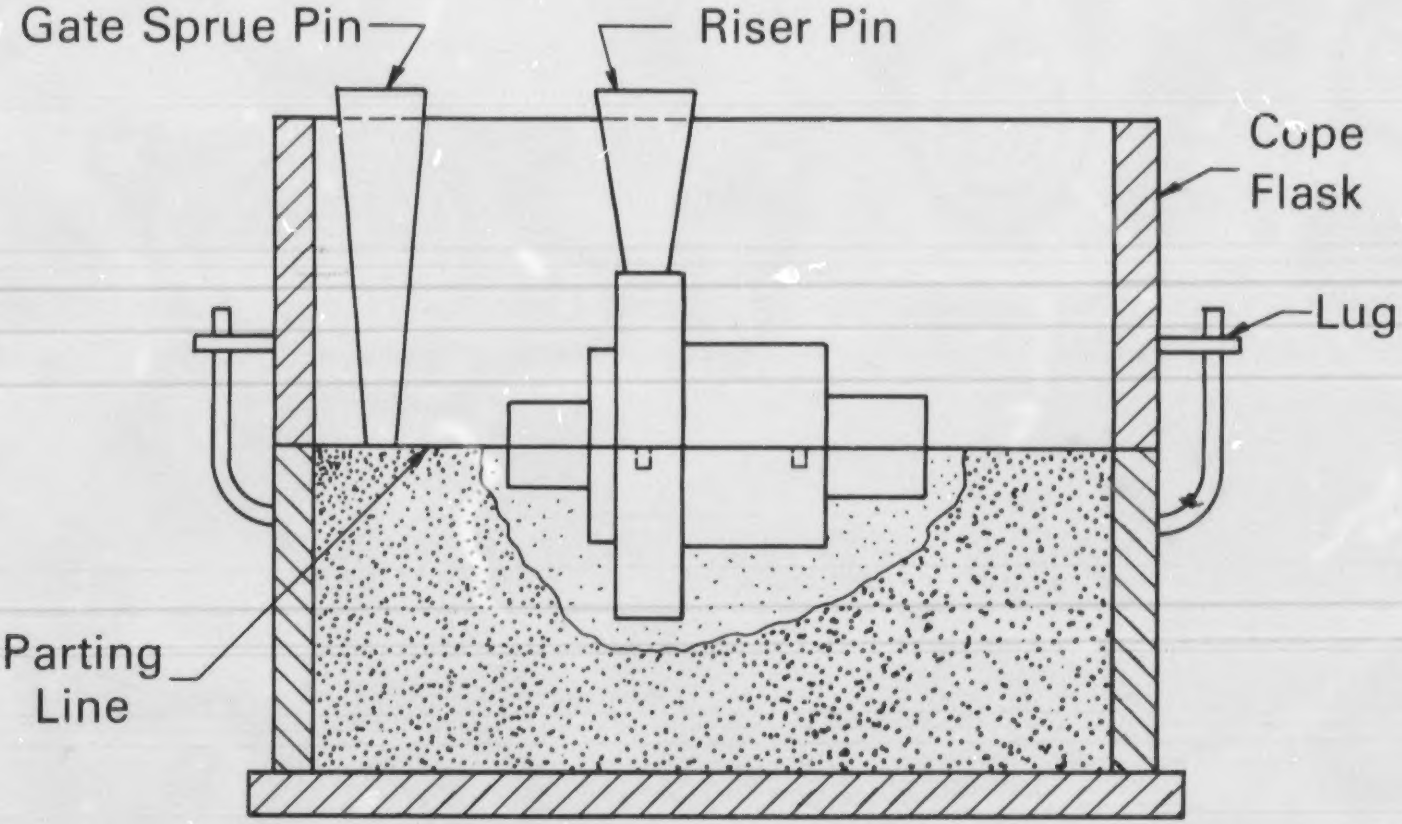


Drag Half of Pattern (With Dowel Holes)
Molding Sand
Drag Flask
Alignment Pins
Mold Board

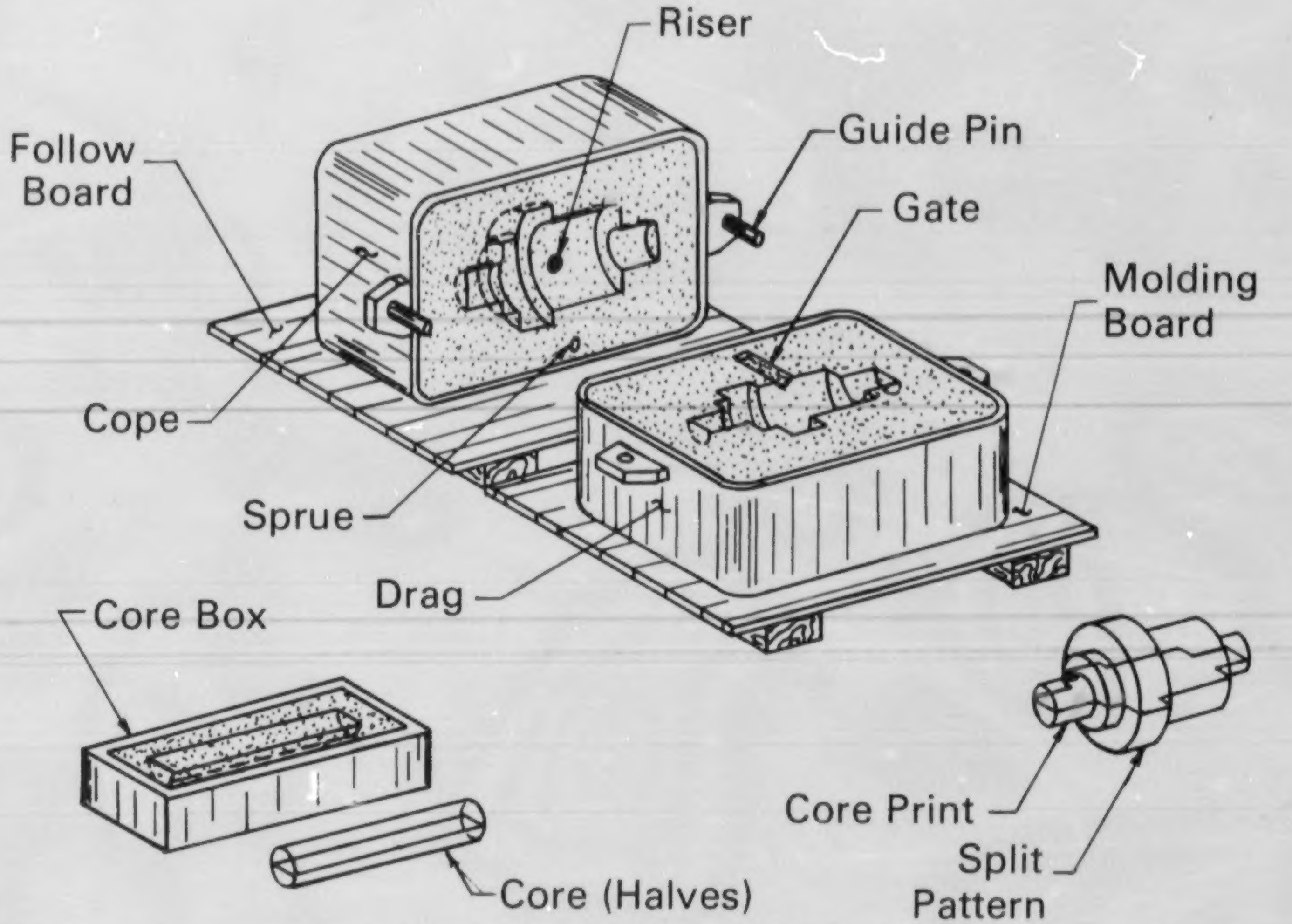
After Rolling Over the Drag


Parting Surface
Bottom Board

Preparing to Ram Molding Sand in Cope


Gate Sprue Pin
Riser Pin
Cope Flask
Lug
Parting Line

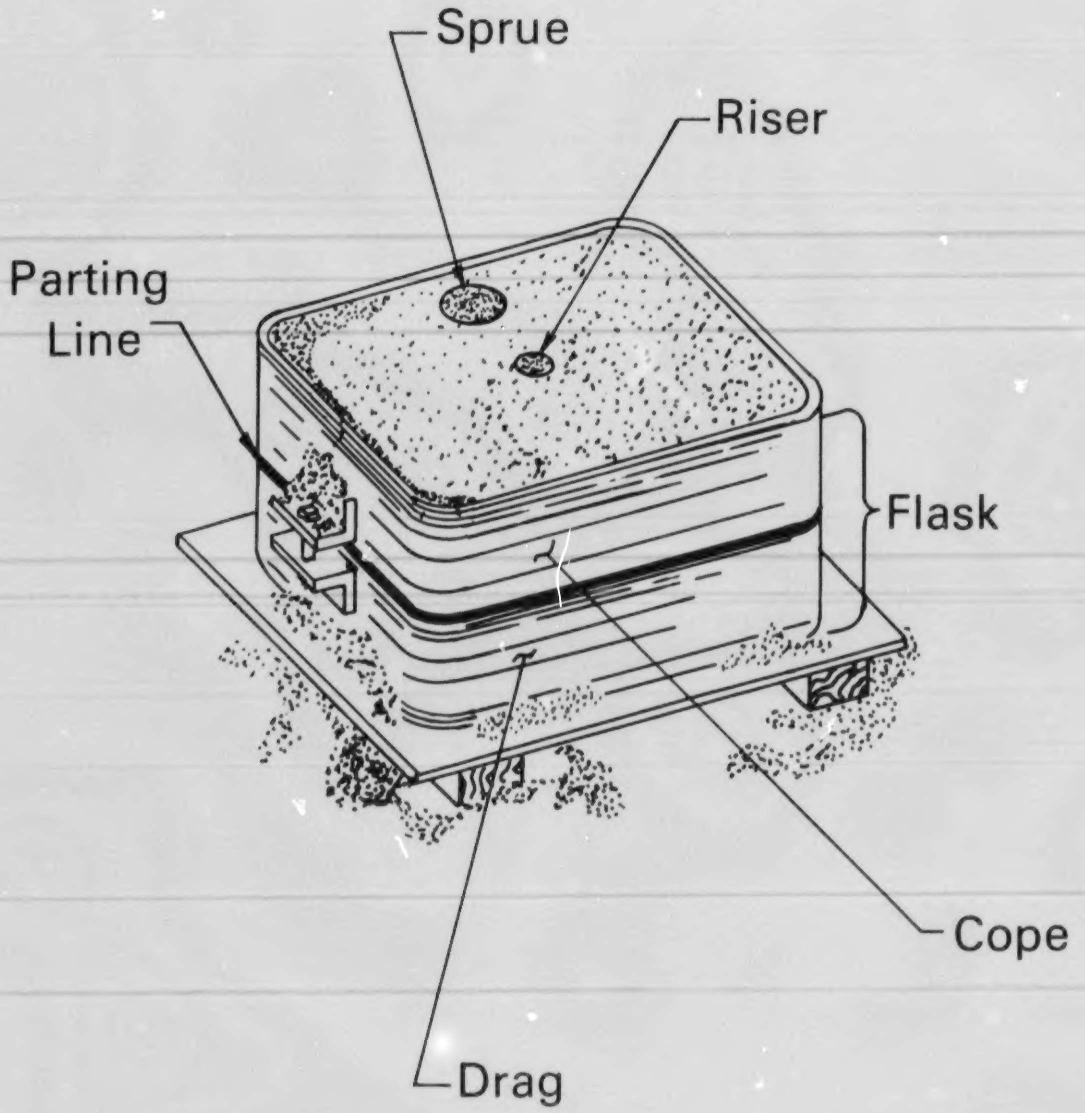
Complete Mold - Separated


Riser
Guide Pin
Follow Board
Gate
Molding Board
Cope
Sprue
Drag
Core Box
Core Print
Split Pattern
Core (Halves)

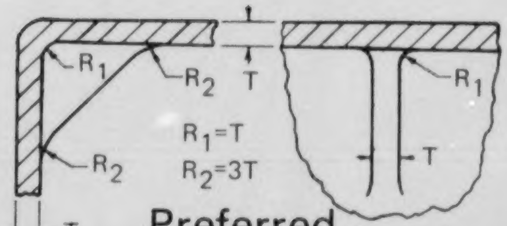
TM 10

MD - 651

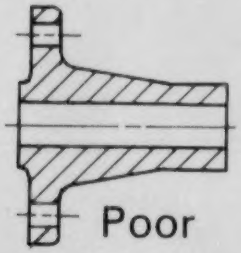
Completed Mold


Sprue
Riser
Parting Line
Flask
Cope
Drag

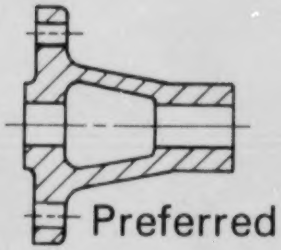
Design of Castings


R1
R2
T
R1=T
R2=3T
R2
T
R1
T
T

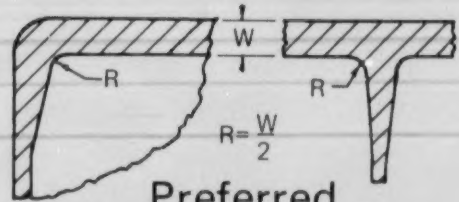
Preferred



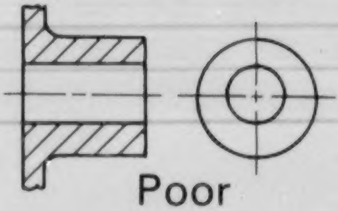
Poor



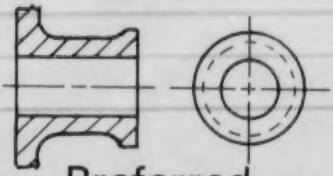
Preferred



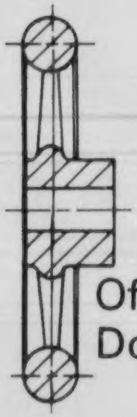
Preferred



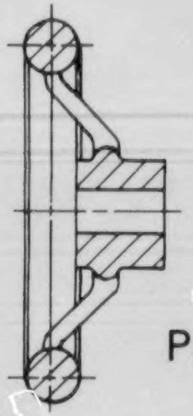
Poor



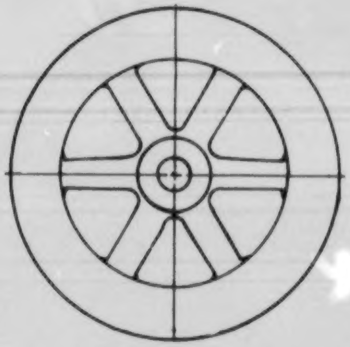
Preferred



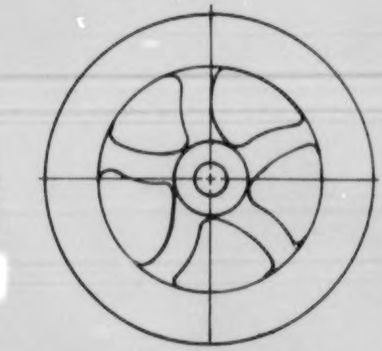
Often Done



Preferred



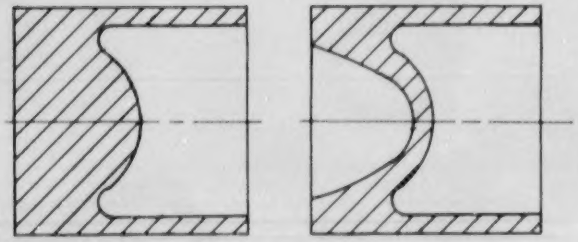
Often Done



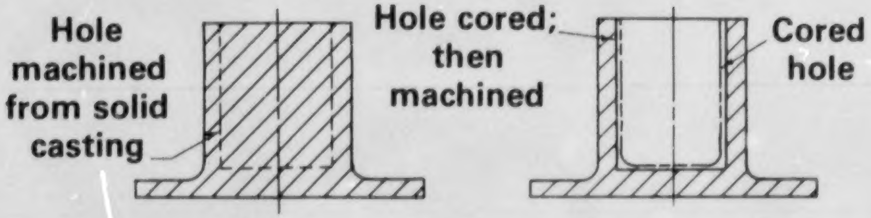
Preferred

Design of Castings

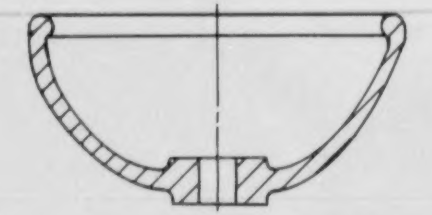
(Continued)



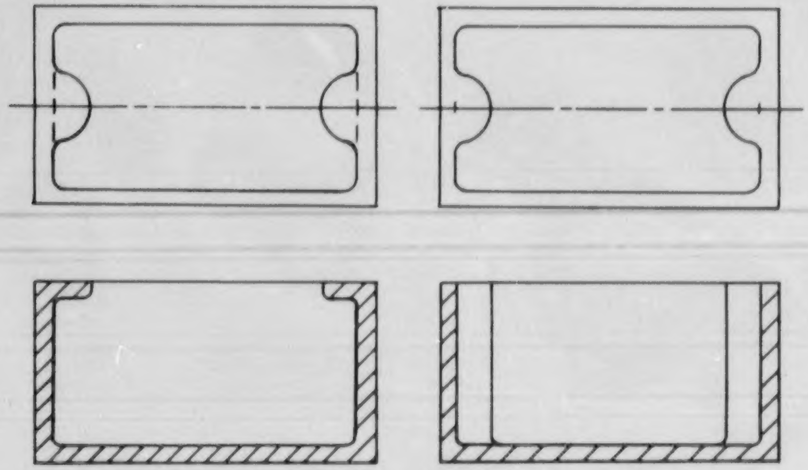
Poor Preferred


Hole machined from solid casting
Hole cored; then machined
Cored hole

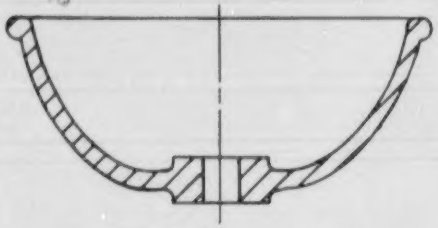
Poor Preferred



Poor

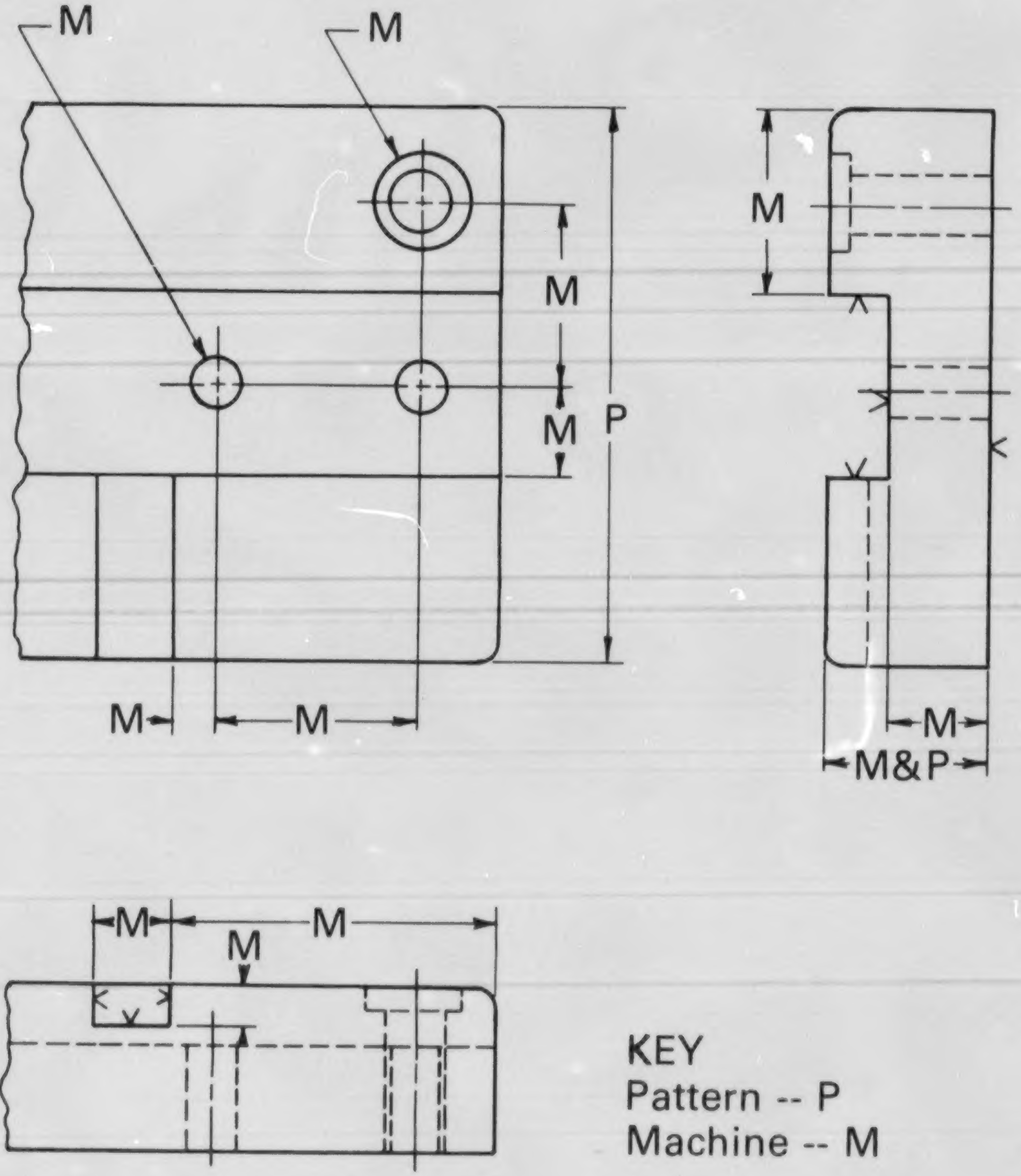


Poor Preferred



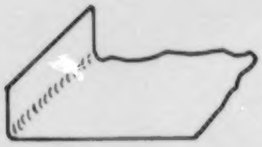
Preferred

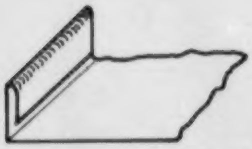
Pattern and Machine Dimensions

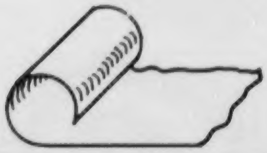

M
M
M
M
P
M
M
M
M
M&P
M
M
M

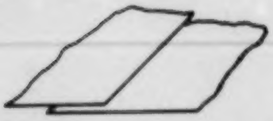
KEY
Pattern -- P
Machine -- M

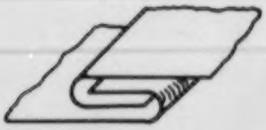
Sheet Metal Hems and Joints

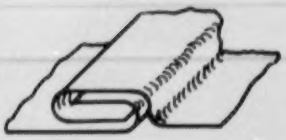

Single Flange

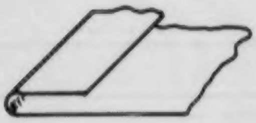

Double Flange

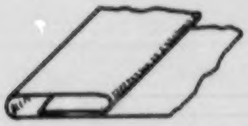

Rolled Edge

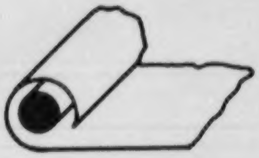

Lap Seam

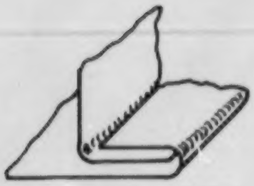

Plain Flat Seam

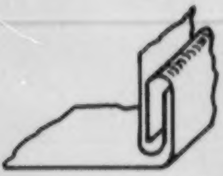

Grooved Seam

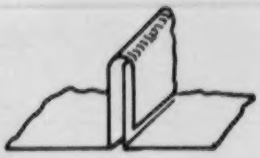

Single Hem


Double Hem

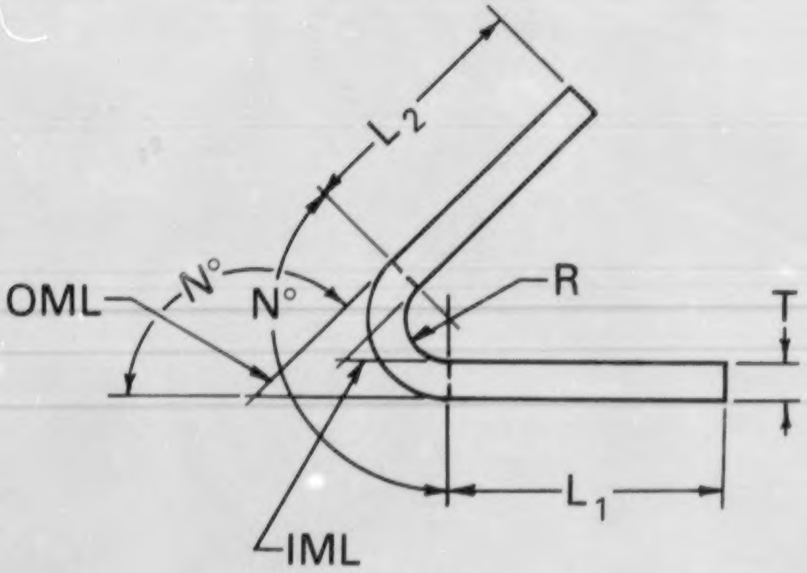

Wired Edge


Single Seam


Double Seam


Standing Seam

Bend Allowance



BA = Bend Allowance

R = Radius

T = Metal Thickness

N° = Number of Degrees in Bend

Length = $L_1 + L_2 + BA$

$BA = (.017453R + .0078T)N°$

Example: If R = .5, T = .10, N° = 120° --

$$\begin{aligned} BA &= (.017453R + .0078T)N° \\ &= [.017453(.5) + .0078(.10)]120 \\ &= .1872 \end{aligned}$$

MANUFACTURING PROCESSES
UNIT IX

ASSIGNMENT SHEET #1–CALCULATE BEND ALLOWANCE FOR SHEET METAL

Directions: Calculate bend allowances for these problems using the following formula:

$BA = (.017453R + .0078T)\ N$

Problems:

A. Radius: 4"
Thickness: .75"
Number of degrees of bend: 90°

BA = ____________________

B. Radius: 6"
Thickness: .60"
Number of degrees of bend: 120°

BA = ____________________

C. Radius: .75"
Thickness: .25"
Number of degrees of bend: 90°

BA = ____________________

D. Radius: .25"
Thickness: .125"
Number of degrees of bend: 85°

BA = ____________________

E. Radius: 1.5"
Thickness: .50"
Number of degrees of bend: 30°

BA = ____________________

F. Radius: 1.25"
Thickness: .25"
Number of degrees of bend: 120°

BA = ____________________

MANUFACTURING PROCESSES
UNIT IX

ASSIGNMENT SHEET #2--DESIGN A CASTING PART

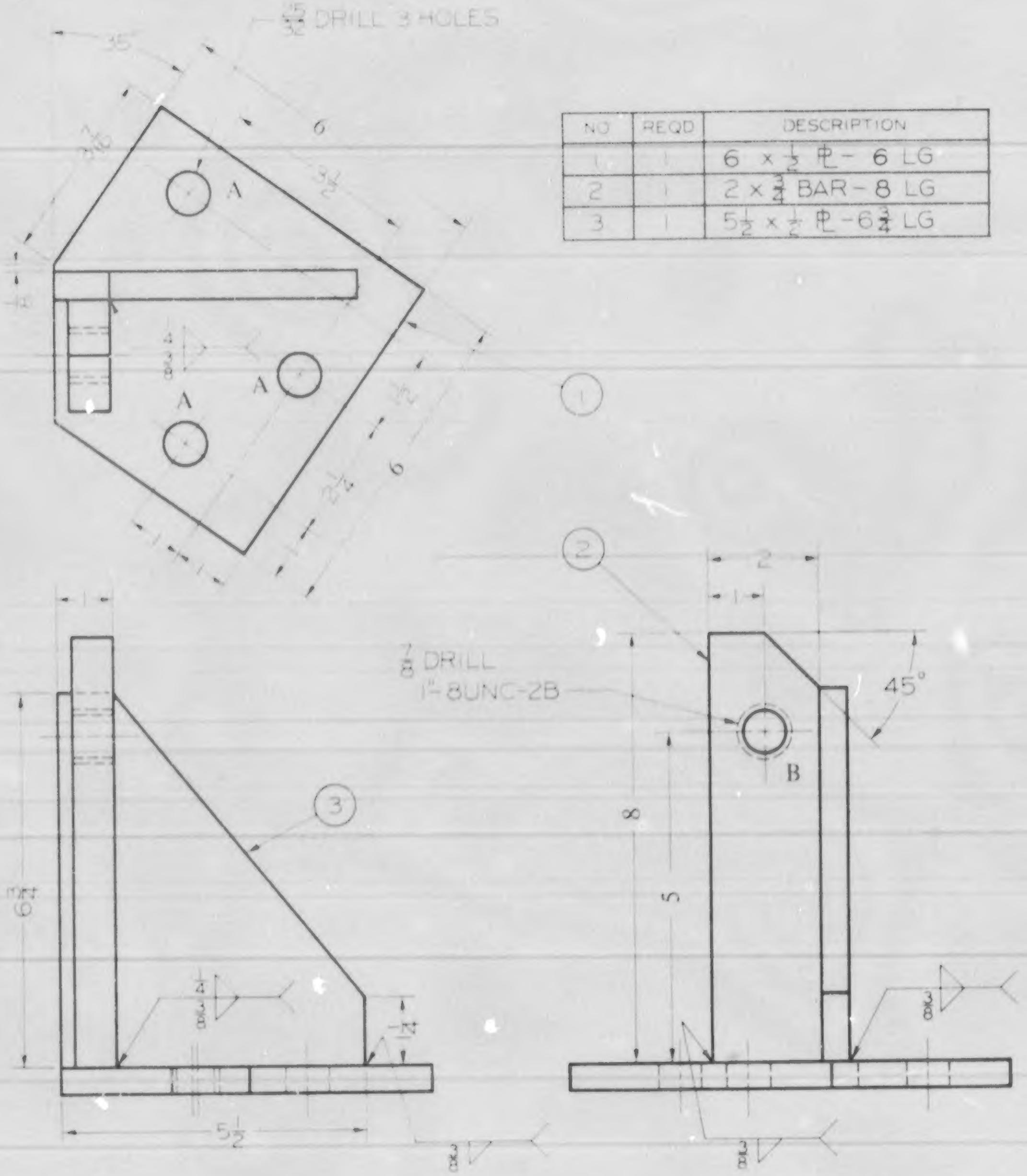
Directions: Select a workpiece assigned below that has been welded or a workpiece selected by instructor. Redesign the workpiece into a casting drawing on "B" size vellum or other media assigned by instructor. Include all dimensions and notes necessary for a pattern maker.

Problems:

A. Include the following changes:

   1. 1/8" high by 1 1/4" DIA boss on holes "A"
   2. Finish "V" bottom surface, bosses, and left side
   3. Fillets and rounds 1/8" radius
   4. Add 1/4" high by 1 1/2" DIA boss to front and back of hole "B"
   5. Finish boss surfaces

ASSIGNMENT SHEET #2

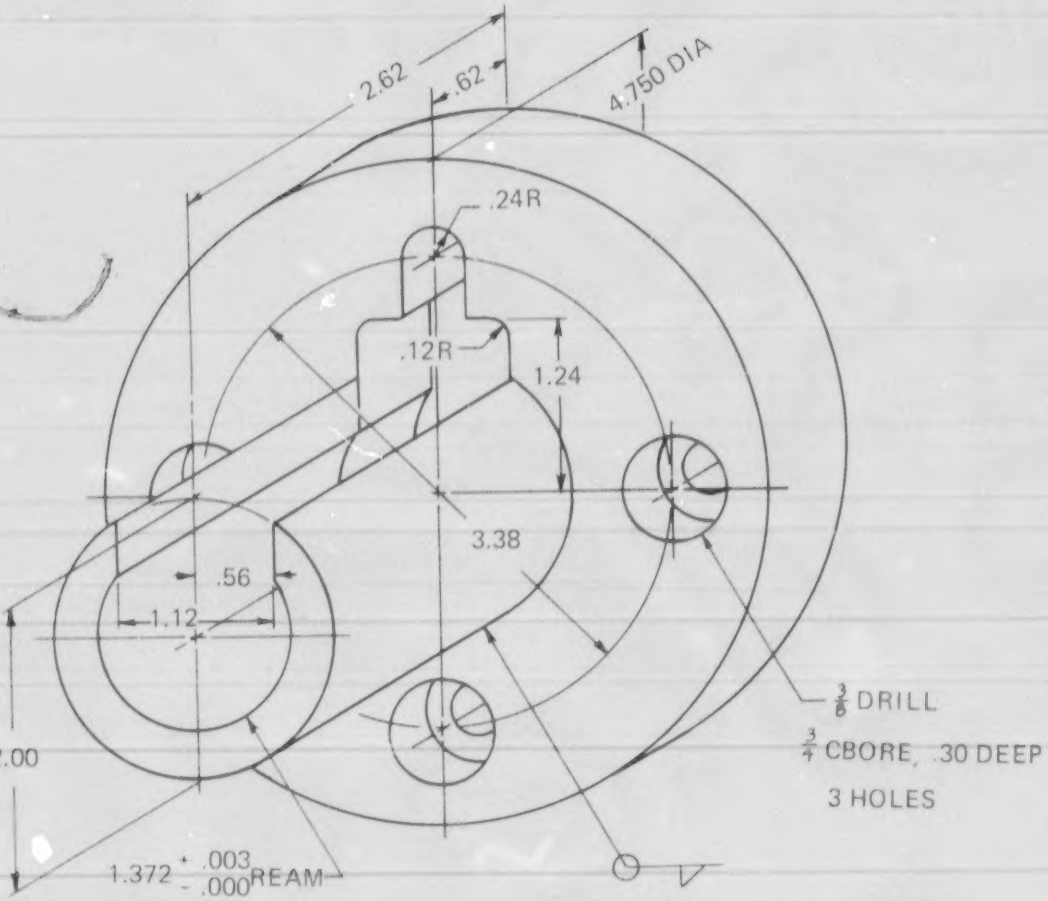

$\frac{15}{32}$ DRILL 3 HOLES
35°
6
$3\frac{7}{16}$
$3\frac{1}{2}$
A
A
A
$\frac{1}{8}$
4
$\frac{3}{8}$
①
$1\frac{1}{2}$
$2\frac{1}{4}$
6
1
1
②
2
1
$\frac{7}{8}$ DRILL
1"-8UNC-2B
45°
B
8
5
③
$6\frac{3}{4}$
$\frac{1}{4}$
$\frac{3}{8}$
$1\frac{1}{4}$
$5\frac{1}{2}$
$\frac{3}{8}$
$\frac{3}{8}$
$\frac{3}{8}$

NO	REQD	DESCRIPTION
1	1	$6 \times \frac{1}{2}$ PL – 6 LG
2	1	$2 \times \frac{3}{4}$ BAR – 8 LG
3	1	$5\frac{1}{2} \times \frac{1}{2}$ PL – $6\frac{3}{4}$ LG

ASSIGNMENT SHEET #2

B. Include the following changes:

1. Finish front and back surfaces
2. Use 1/4" radius for rounds
3. Use 3/8" radius for fillets


2.62
.62
4.750 DIA
.24R
.12R
1.24
3.38
.56
1.12
2.00
$1.372 {}^{+.003}_{-.000}$ REAM
$\frac{3}{8}$ DRILL
$\frac{3}{4}$ CBORE, .30 DEEP
3 HOLES

CENTERING BUSHING

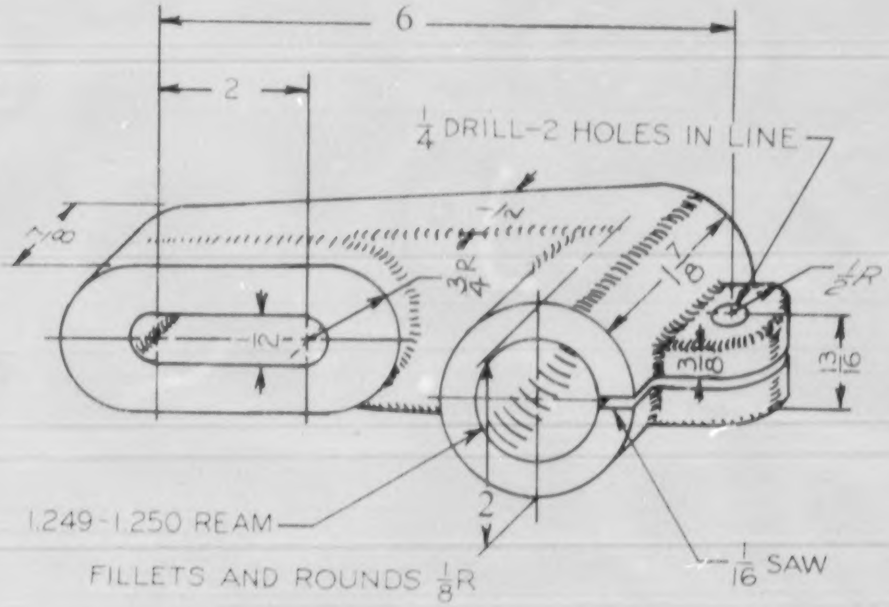
MANUFACTURING PROCESSES
UNIT IX

ASSIGNMENT SHEET #3--DESIGN A FORGING PART

Directions: Select a workpiece assigned below that has been cast or a workpiece selected by instructor. Redesign the workpiece into a forging drawing on "B" size vellum or other media assigned by instructor. All draft angles are to be 7°. If necessary, redesign shape, but hold bearing surfaces true. Include all dimensions and notes necessary for a forging design.

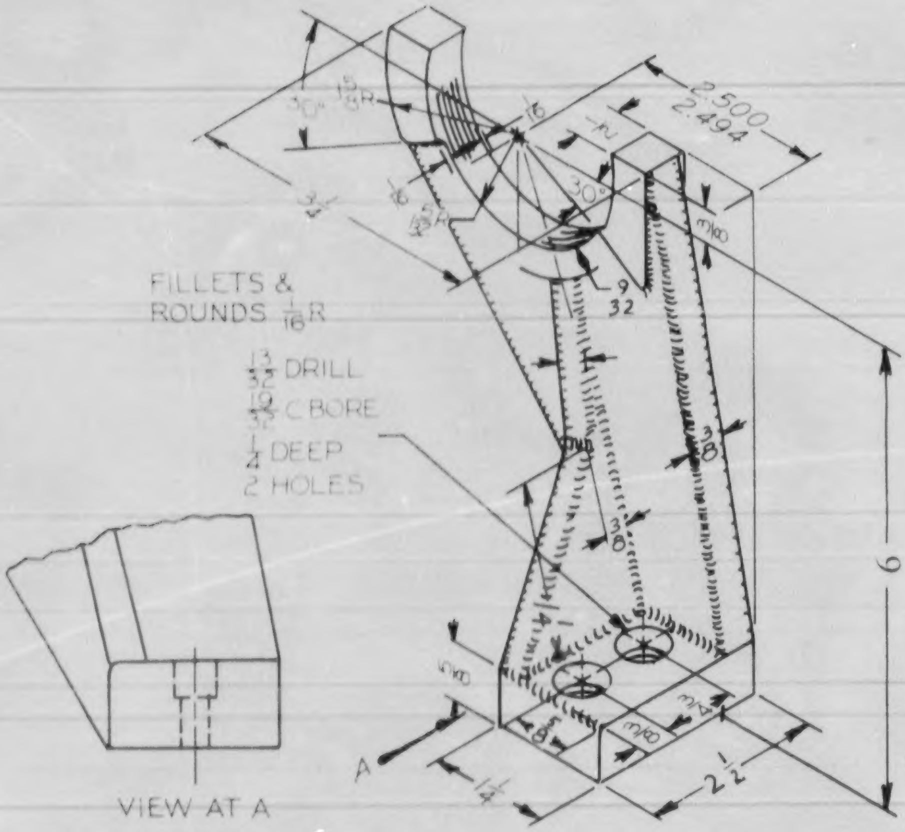
Problems:

A.


6
2
$\frac{1}{4}$ DRILL–2 HOLES IN LINE
$\frac{7}{8}$
$\frac{1}{2}$
$\frac{3}{4}$R
$\frac{1}{2}$
$1\frac{7}{8}$
$\frac{1}{2}$R
$\frac{3}{8}$
$\frac{13}{16}$
1.249 - 1.250 REAM
2
FILLETS AND ROUNDS $\frac{1}{8}$R
$\frac{1}{16}$ SAW

ASSIGNMENT SHEET #3

B.


2.500
2.494
1/2
30°
30°
1 5/8 R
1/16
3 1/4
1/16
5/8 R
9/32
FILLETS & ROUNDS 1/16 R
13/32 DRILL
19/32 C BORE
1/4 DEEP
2 HOLES
3/8
3/8
3/8
1
1/4
6
5/8
5/8
3/8
3/4
1 1/4
2 1/2
A
VIEW AT A

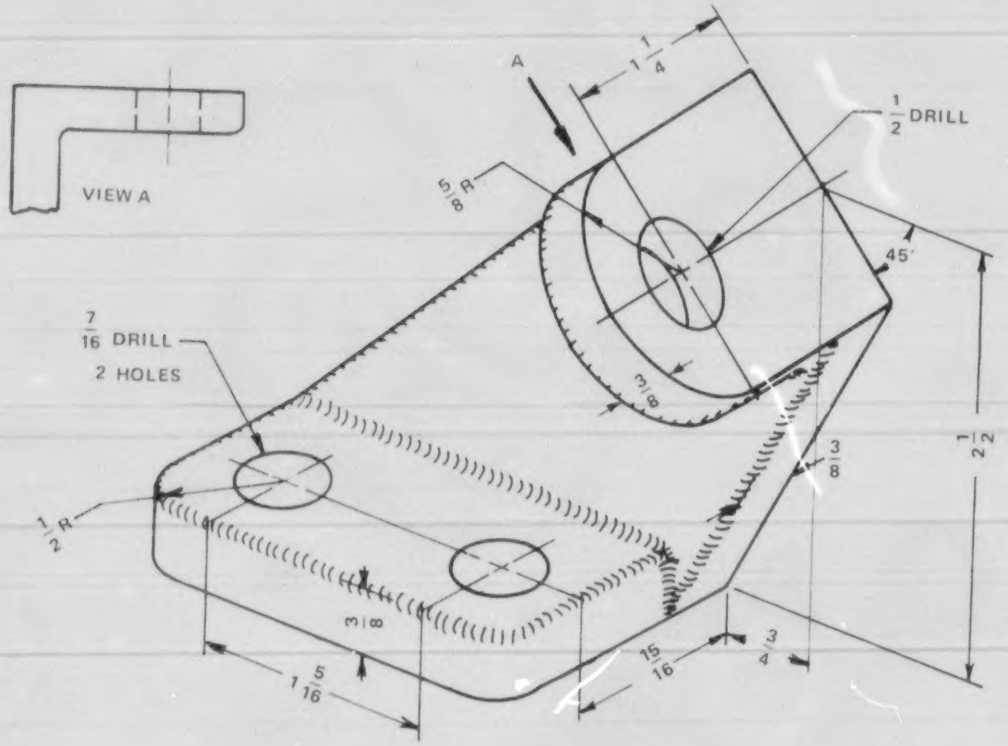
MANUFACTURING PROCESSES
UNIT IX

ASSIGNMENT SHEET #4--DESIGN A WELDED PART

Directions: Select a workpiece assigned below that has been cast or a workpiece selected by instructor. Redesign the workpiece into a welded assembly on "B" size vellum or other media assigned by instructor. Include all dimensions, symbols, and notes for the welded assembly. Also include a parts list of raw stock.

Problems:

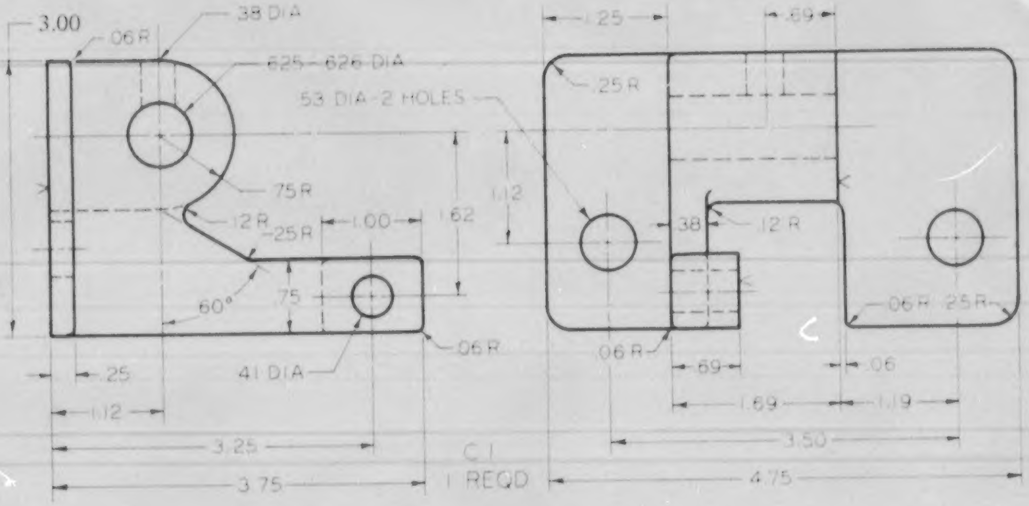
A.


VIEW A
A
$1\frac{1}{4}$
$\frac{1}{2}$ DRILL
$\frac{5}{8}$ R
45°
$\frac{7}{16}$ DRILL
2 HOLES
$\frac{3}{8}$
$\frac{1}{2}$ R
$\frac{3}{8}$
$2\frac{1}{2}$
$\frac{3}{8}$
$1\frac{5}{16}$
$\frac{15}{16}$
$\frac{3}{4}$

BRACKET

ASSIGNMENT SHEET #4

B.


3.00
.06 R
.38 DIA
.625-.626 DIA
.53 DIA-2 HOLES
.75 R
.12 R
.25 R
1.00
1.62
60°
.75
.41 DIA
.06 R
.25
1.12
3.25
3.75
C.I.
1 REQD
1.25
.69
.25 R
1.12
.38
.12 R
.06 R
.25 R
.06 R
.69
.06
1.69
1.19
3.50
4.75

BRACKET BEARING

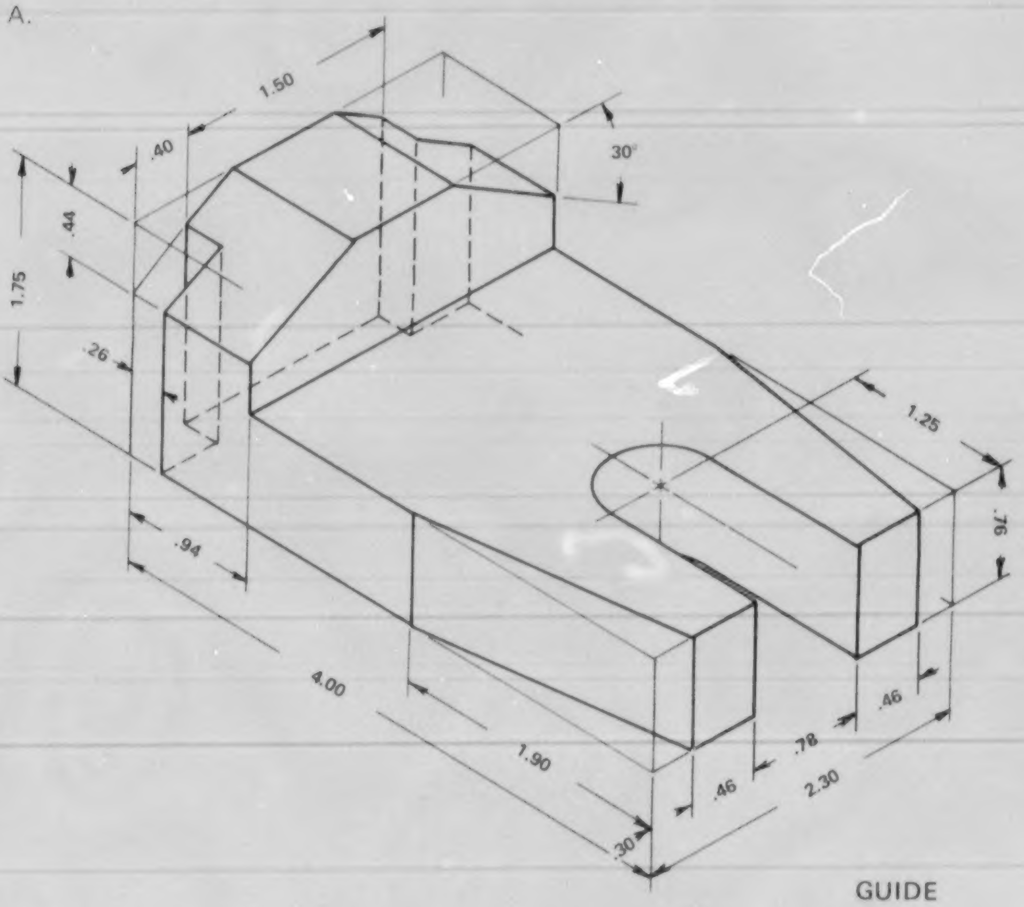
MANUFACTURING PROCESSES
UNIT IX

ASSIGNMENT SHEET #5--DESIGN A THERMOPLASTIC PART

Directions: Select a workpiece below or a workpiece selected by instructor. Design a thermoplastic workpiece to be injection molded on "B" size vellum or other media selected by instructor. Draw four parts attached to a common core. These four parts will be injection molded at one time.

Problems:

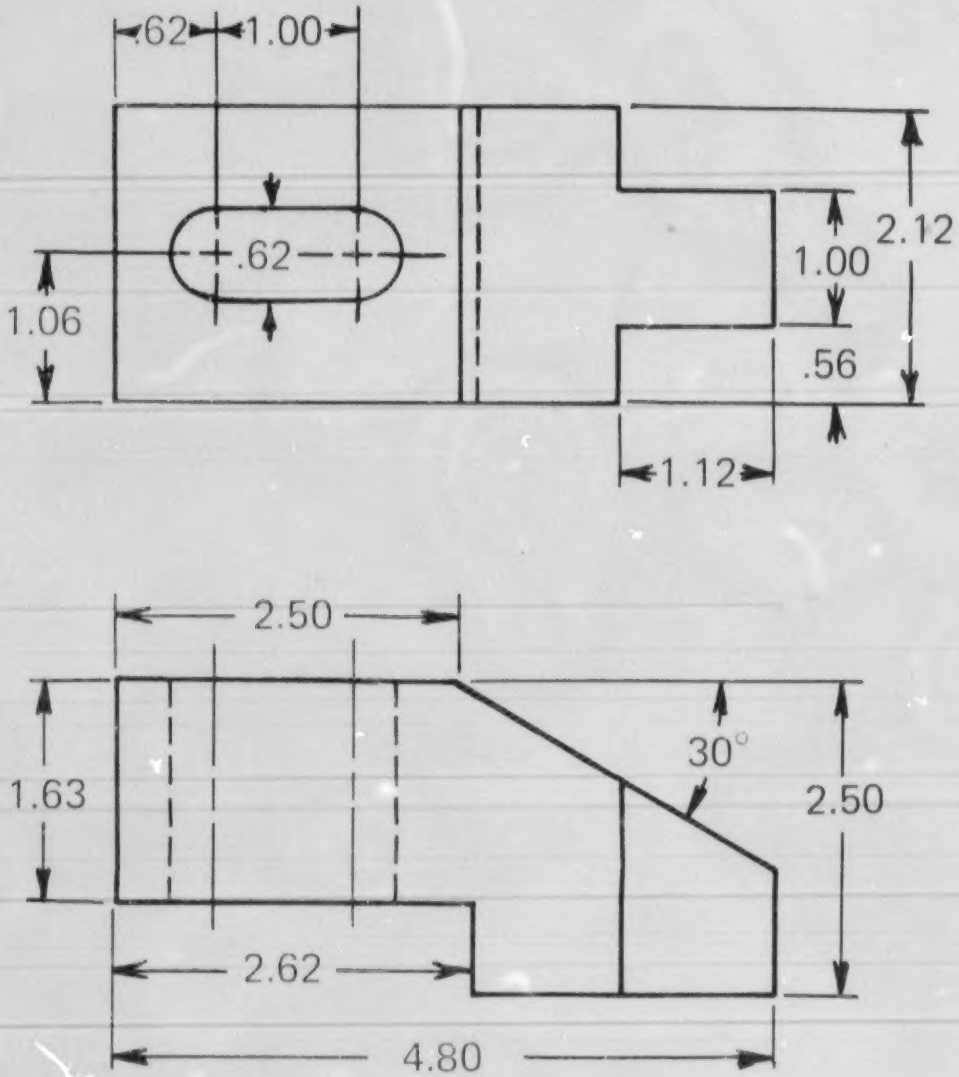
A.


1.50
.40
30°
.44
1.75
.26
1.25
.76
.94
4.00
.46
1.90
.78
.46
2.30
.30

GUIDE

ASSIGNMENT SHEET #5

B.


.62
1.00
.62
1.06
2.12
1.00
.56
1.12
2.50
30°
1.63
2.50
2.62
4.80

MANUFACTURING PROCESSES
UNIT IX

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. [.017453 (4) + .0078 (.75)] 90 = 6.81

B. [.017453 (6) + .0078 (.60)] 120 = 13.13

C. [.017453 (.75) + .0078 (.25)] 90 = 1.35

D. [.017453 (.25) + .0078 (.125)] 85 = .45

E. [.017453 (1.5) + .0078 (.50)] 30 = .90

F. [.017453 (1.25) + .0078 (.25)] 120 = 2.85

Assignment Sheets 2-5--Evaluated to the satisfaction of the instructor

MANUFACTURING PROCESSES
UNIT IX

NAME ______________________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. Bombardment of a workpiece by grit driven by linear oscillation of the tool

_____b. Process of melting materials and blowing the melted metal on a surface

_____c. Removal of metal by spark in the presence of a coolant

_____d. "Lost wax" process of pouring a sand mixture around a wax pattern; the casting is made by pouring molten metal into the hardened sand shell melting and forcing the wax out

_____e. Metal in plastic state formed by mechanical working

_____f. Special body designed to produce a special cavity in or on a casting

_____g. Metal object formed by pouring molten metal into a mold until solidified

_____h. Reverse plating process of material removal

_____i. Use of an acid to dissolve metal in areas except where acid resist is used

_____j. Pulsing technique by accelerated electrons that heat and cool an area

_____k. Chemical removal of a metal from the workpiece

_____l. Process using thin sand resin shells molded of the pattern and molten metal is poured into the cavity

_____m. Forming or plastic deforming metals while metal is cold

_____n. Precise removal of small amounts of metal by a concentrated focus of intense heat

1. Casting
2. Pattern
3. Permanent mold casting
4. Extrusion
5. Die casting
6. Centrifugal casting
7. Automation
8. Investment casting
9. Shell molding
10. Injection molding
11. Hot working metal
12. Cold working metal
13. Machining operations
14. Electroplating

_____o. Operation of machine tools by automatic programmed cutting sequences using numerical data stored on paper, magnetic tape, tabulating cards, computer storage, or direct information to produce accurate machining of complex geometrical surfaces

_____p. Ramming of hot plastic into a mold

_____q. Covering a metal by electro-deposits of a thin coating of the same or other metal

_____r. To change the shape, finish, and size by removing material from the workpiece

_____s. Process of pouring metal into a revolving mold

_____t. Form used to make a cavity in sand mold

_____u. Process of forcing hot metal into a metal mold or die

_____v. Casting produced with metal molds plus hydrostatic pressure

_____w. The process of melting or melting together materials

_____x. The process of pushing metal through a shape-formed die

_____y. A mechanical or chemical process to improve part appearance, surface hardness, coatability, and resistance to wear

_____z. A numerical control system using a special purpose computer to operate machine tools

_____aa. An N/C machine or system of machines that control the sequence of operations, tool movement, or material movement with very little, if any, assistance from the operator

_____bb. A machine that has the capability to transfer a workpiece from one operation to another operation within the machine or to another machine

15. Fusion
16. Chemical milling
17. Flame spraying
18. Transfer machine
19. Laser machining
20. Ultrasonic machining
21. Electron beam machining
22. Electronic discharge machining
23. Electro-chemical machining
24. Chemical machining
25. Computer numerical control machinery
26. Numerical control machining
27. Surface preparation
28. Injection molding
29. Core

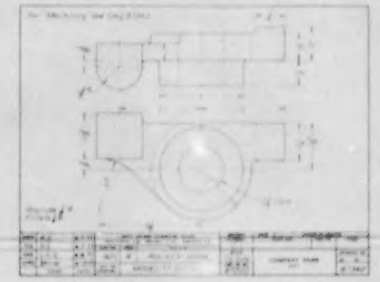
2. State three purposes of manufacturing processes.

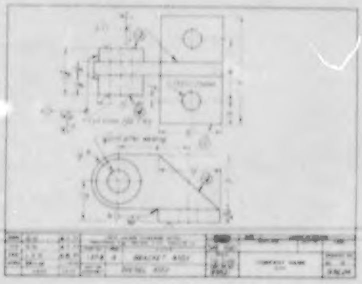
a. ____

b. ____

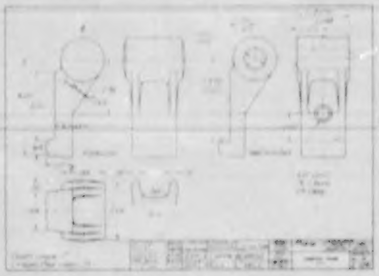
c. ____

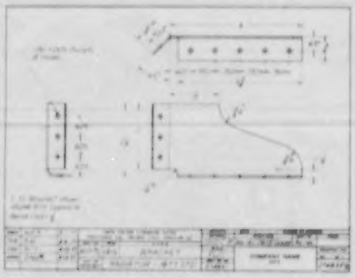
3. Identify principal types of drawings for manufacturing processes.





a. ______________________________ b. ______________________________





c. ______________________________ d. ______________________________

4. Match the casting terms on the right with the correct definitions.

_____a. Complete mold

_____b. Top half of the flask

_____c. Middle part of the flask

_____d. Relief for air and molten metal to rise

_____e. Tapered hole in the cope of the casting mold to pour molten metal into the mold cavity

_____f. Bottom half of the flask

_____g. Pattern taper for easy removal of pattern from mold

_____h. Line of seperation

_____i. Devices to align drag and cope

_____j. Opening for the molten metal to flow between the sprue and the mold cavity

1. Riser
2. Flask
3. Sprue
4. Parting line
5. Draft
6. Drag
7. Cope
8. Cheek
9. Gate
10. Alignment pins

5. Select true statements concerning design of a casting by placing an "X" in the appropriate blanks.

______a. Abrupt changes in sections aid in the design of castings

______b. Keep wall thickness of sections uniform

______c. Avoid internal stresses

______d. Use maximum number of adjoining sections

______e. Fillet radii should be larger than rib thicknesses

______f. A finish allowance or extra metal must be included for machining

______g. Even number of spokes is better than odd number so all stress will be along opposite spokes

6. Distinguish between pattern and machine dimensions in the illustration by placing a "P" for pattern dimension and an "M" for machine dimensions in the corresponding blanks.

______a.

______b.

______c.

______d.

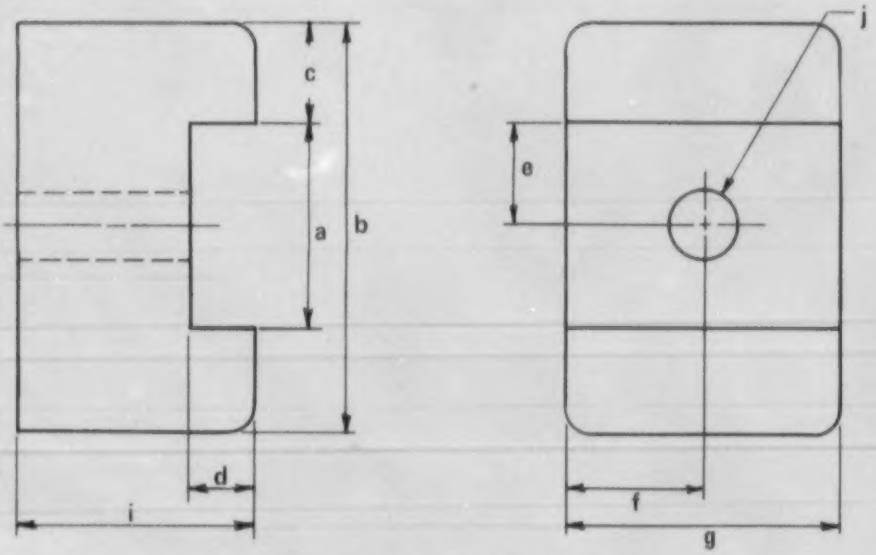
______e.

______f.

______g.

______h.

______i.



7. Match the forging terms on the right with the correct definitions.

______a. Plane perpendicular to the direction of pressure	1. Parting line
	2. Die
______b. Line where dies meet and separate	3. Die closure
______c. Added amount to the die when dies do not close	4. Draft
______d. Measurement of displacement of two opposing dies in the direction parallel to the parting line of the dies	

_____ e. Slight excess thin fin of material surrounding a forging at the parting line

_____ f. Taper of surfaces to allow easy removal from the die

_____ g. Device used in shaping or stamping an object or flat material

5. Parting plane
6. Flash
7. Match tolerance

8. Select true statements concerning design of a forging by placing an "X" in the appropriate blanks.

_____ a. Sharp corners should be designed in castings

_____ b. Use strippers and ejectors when little or no draft is used

_____ c. Have small fillet if material is flowing toward fillet

_____ d. Allow generous tolerances for dies in areas of greatest pressure and flow

9. Match the welding terms on the right with the correct definitions.

_____ a. Heating of metal by hot flame and melting of welding rod as a filler metal

_____ b. Heated metal is forced together under pressure

_____ c. Most common process which uses electric arc to melt edges and melted electrode as additional material

_____ d. Chemical reaction between powdered aluminum and powdered metal oxide which causes them to be welded together

_____ e. A heavy current is passed through parts in contact which melts and fuses the parts together

_____ f. Parts are heated by electric current to melt and fuse parts together

_____ g. A method of testing materials, usually samples, that destroys their usefulness

_____ h. An arc welding process in which the arc is constricted in a hot ionized gas flowing through an orifice

_____ i. Gas tungsten inert shielding arc welding using a metal electrode

_____ j. Gas metal inert shielding arc welding using a metal electrode

_____ k. A method of testing materials without impairing the usefulness of the material

1. Arc welding
2. Destructive testing
3. Forge welding
4. Induction welding
5. MIG
6. Resistance welding
7. Plasma welding
8. Gas welding
9. Nondestructive testing
10. Thermit welding
11. TIG

10. Select true statements concerning design procedures for a welded assembly by placing an "X" in the appropriate blanks.

______a. Use standard rolled shapes such as I beams, channels, zees, and tees

______b. Design for calculated load to avoid wasting materials

______c. Use shallow sections so bending will be needed

______d. Design with maximum number of pieces

______e. Eliminate beveling if deep-penetrating arc can be used

______f. Use maximum root opening so a great deal of filler metal can be used

______g. Place welds on longest seams

11. Match the machines on the right with the correct processes.

______a. Making straight or circular cuts in a workpiece

______b. Cutting the workpiece by rotating the workpiece against the edge of the tool

______c. Cutting circular holes in the workpiece by a rotating tool

______d. Removing tiny particles from the surface of the workpiece by abrasive action

______e. Cutting the workpiece by a rotating tool; the workpiece is then moved back into position for the next cut

______f. Cutting by tools going back and forth on workpiece while workpiece is automatically advanced

______g. Pulling or pushing a broaching tool over the workpiece surface to machine simple or complex contours

1. Turning machines
2. Milling machines
3. Drill press
4. Shaper and planer
5. Sawing machines
6. Broaching machines
7. Grinding machines

12. Name four advantages of numerical control machinery.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

13. Match plastic manufacture terms on the right with the correct definitions.

______ a. Air is blown into heated plastic forcing it against the mold sides

______ b. Pressure and heat cause material to flow in a mold

______ c. Fusing together of thermoplastic materials

______ d. Plastic is forced through die of the desired shape

______ e. Plunger and high frequency preheating mold plastic in a mold cavity

______ f. Thermoplastic material is injected into a mold and cooled

______ g. Preheating plastic sheets until limp, followed by vacuum forming over a mold

______ h. Combination of materials by heat and pressure to form a single piece

______ i. Process in which plastisol plastic is fused while in a rotating mold

1. Thermoplastic welding
2. Laminating
3. Compression molding
4. Transfer molding
5. Injection molding
6. Rotational molding
7. Extrusion
8. Blow molding
9. Thermoforming

14. Select true statements concerning methods of fabricating plastics.

______ a. Machining is used on flexible thermoplastics

______ b. Welding is used for joining rigid sheets of plastic

______ c. Forming is used on rigid plastics

______ d. Forming is used on flexible thermoplastics

15. Select true statements concerning design procedures for plastics by placing an "X" in the appropriate blanks.

______ a. Any wall thickness should not exceed 1/8" thick

______ b. Draft or taper of 7° to 10° is desirable

______ c. Holes larger than 1/8" in diameter must be drilled or formed after molding

______ d. Ribs and bosses must have 5° tapers

16. Match sheet metal processing terms on the right with the correct definitions.

______a. Stretching sheet over die in the form of the final product

______b. Stretching sheet metal and then forming by dies

______c. A pattern or shape in two dimensions for sheet metal

______d. Cutting metal by shearing action

______e. Using high energy to shape metal such as explosive or magnetic forming

______f. Forming a sheet of metal over a mandrel while the sheet is rotating

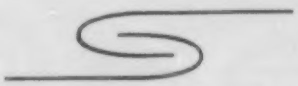
______g. An overbending operation to allow for the material to spring back into the desired shape

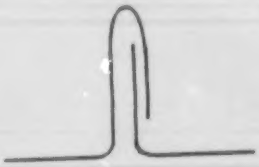
______h. To form corners, edges, and seams in sheet metal

______i. Holes drilled or punched at intersection of bends to relieve strain which would cause metal to crack or buckle

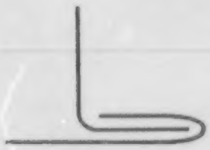
1. Bend relief holes
2. Metal spinning
3. Stretch forming
4. High energy forming
5. Spring back
6. Shearing
7. Drawing
8. Bending
9. Development

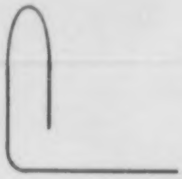
17. Identify the following sheet metal hems and joints.





a. ______________________________ b. ______________________________





c. ______________________________ d. ______________________________

18. Calculate bend allowance for 5 gage thick (.1819) sheet metal. Radius = .5"; Number of degrees in bend = 75°.

$BA = (.017453R + .0078T)N$

BA = ______________________

19. Demonstrate the ability to:

a. Design a casting part.

b. Design a forging part.

c. Design a welded part.

d. Design a thermoplastic part.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

MANUFACTURING PROCESSES
UNIT IX

ANSWERS TO TEST

1. a. 20
   b. 17
   c. 22
   d. 8
   e. 11
   f. 29
   g. 1
   h. 23
   i. 24
   j. 21
   k. 16
   l. 9
   m. 12
   n. 19
   o. 26
   p. 28
   q. 14
   r. 13
   s. 6
   t. 2
   u. 5
   v. 3
   w. 15
   x. 4
   y. 27
   z. 25
   aa. 7
   bb. 18

2. a. Removing material from original part
   b. Adding material to original part
   c. Spreading material to other areas

3. a. Casting
   b. Welding
   c. Forging
   d. Sheet metal

4. a. 2
   b. 7
   c. 8
   d. 1
   e. 3
   f. 6
   g. 5
   h. 4
   i. 10
   j. 9

5. b, c, f

6. a. M
   b. P
   c. M
   d. M
   e. M
   f. M
   g. P
   h. P
   i. M

7. a. 5
   b. 1
   c. 3
   d. 7
   e. 6
   f. 4
   g. 2

8. b, d

9. a. 8
   b. 3
   c. 1
   d. 10
   e. 6
   f. 4
   g. 2
   h. 7
   i. 11
   j. 5
   k. 9

10. a, b, e

11. a. 5
    b. 1
    c. 3
    d. 7
    e. 2
    f. 4
    g. 6

12. Any four of the following:

    a. Greater control over the manufacturing process
    b. Higher cutting rates
    c. Large time savings
    d. Reduction of inventory
    e. Fewer machines and operators required
    f. Less skill required by operators
    g. Reduced scrap and rework
    h. Improved product design

13. a. 8
    b. 3
    c. 1
    d. 7
    e. 4
    f. 5
    g. 9
    h. 2
    i. 6

14. b, d

15. a, d

16. a. 7
    b. 3
    c. 9
    d. 6
    e. 4
    f. 2
    g. 5
    h. 8
    i. 1

17. a. Plain flat seam
    b. Standing seam
    c. Single seam
    d. Double flange

18. $BA = (.017453R + .0078T)N$
    $BA = [(.017453(.5) + .0078\ (.1819)]\ (75)$
    $BA = [.0087265 + .00141882]\ 75$
    $BA = .760$

19. Evaluated to the satisfaction of the instructor

SHEET METAL DEVELOPMENTS
UNIT X

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify true lengths and true sizes of surfaces, construct true lengths and true sizes by rotation, and construct intersections of surfaces and sheet metal developments. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment sheets and by scoring 85 percent on the unit test.

(NOTE: Review "Orthographic Views," "Geometric Construction," and "Auxiliary Views" from *Basic Drafting, Book Two* before attempting this unit.)

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to sheet metal developments with the correct definitions.
2. Distinguish between visualization of near and far points and planes.
3. Arrange in order the steps for constructing an auxiliary view.
4. Identify true length lines and true sizes of three view drawings.
5. Identify point views of lines and edge views of planes.
6. Select true statements concerning important characteristics of rotation.
7. Select elements of single curved surfaces.
8. List methods for finding intersections of surfaces.
9. Name three general groups of developments.
10. Calculate bend allowance.
11. Demonstrate the ability to:
    a. Label points, lines, and planes in views.
    b. Identify true lengths and types of lines.
    c. Identify true sizes and types of planes.
    d. Construct true lengths of lines and true sizes of planes using auxiliary views.
    e. Construct true lengths of lines by rotation.

f. Construct true sizes of planes by rotation.

g. Locate elements of single curved surfaces.

h. Construct intersections of surfaces.

i. Construct intersections of surfaces using two-view method.

j. Construct radial line developments.

k. Construct parallel line developments.

l. Construct special developments using triangulation.

SHEET METAL DEVELOPMENTS
UNIT X

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and assignment sheets.

~~III. Make transparency masters.~~

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Tour a sheet metal fabrication plant.

VII. If possible, have students construct models from sheet metal or cardboard.

(Note: Used aluminum plates from the local newspaper could be a source of metal. Caution the students that sheet metal can cut hands very easily.)

VIII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
  A. Objective sheet
  B. Information sheet
  C. Transparency masters
    1. TM 1--Near and Far Points and Planes
    2. TM 2--Observing Points and Planes
    3. TM 3--Labeling Points, Lines, and Planes
    4. TM 4--Steps for Constructing Auxiliary Views
    5. TM 5--True Lengths of Lines
    6. TM 6--Identifying True Lengths
    7. TM 7--Observing True Size Planes
    8. TM 8--Identifying True Sizes
    9. TM 9--Point Views of Lines

10. TM 10--Edge Views of Planes
11. TM 11--Rotation of a Point
12. TM 12--True Lengths by Rotation
13. TM 13--True Sizes by Rotation
14. TM 14--Elements of Single Curved Surfaces
15. TM 15--Intersections With Edge View Given
16. TM 16--Intersections Using Auxiliary Views
17. TM 17--Intersections of Cylinders
18. TM 18--Developments
19. TM 19--Radial Line Developments--Pyramids
20. TM 20--Radial Line Developments--Cones
21. TM 21--Parallel Line Developments--Prisms
22. TM 22--Parallel Line Developments--Cylinders
23. TM 23--Triangulation

D. Assignment Sheets

1. Assignment Sheet #1--Label Points, Lines, and Planes in Views
2. Assignment Sheet #2--Identify True Lengths and Types of Lines
3. Assignment Sheet #3--Identify True Sizes and Types of Planes
4. Assignment Sheet #4--Construct True Lengths of Lines and True Sizes of Planes Using Auxiliary Views
5. Assignment Sheet #5--Construct True Lengths of Lines by Rotation
6. Assignment Sheet #6--Construct True Sizes of Planes by Rotation
7. Assignment Sheet #7--Locate Elements of Single Curved Surfaces
8. Assignment Sheet #8--Construct Intersections of Surfaces
9. Assignment Sheet #9--Construct Intersections of Surfaces Using Two-View Method
10. Assignment Sheet #10--Construct Radial Line Developments
11. Assignment Sheet #11--Construct Parallel Line Developments
12. Assignment Sheet #12--Construct Special Developments Using Triangulation

E. Answers to assignment sheets

F. Test

G. Answers to test

II. References

A. Giesecke, Frederick E., et. al. *Technical Drawing,* New York 10022: Macmillan Publishing Co., Inc., 1980.

B. Pare, E. G., Loving, R. O., and Hill, I. L. *Descriptive Geometry Metric,* 5th ed. New York: Macmillan Publishing Co., Inc., 1977.

C. Earle, James H. *Descriptive Geometry.* 2nd ed. Reading, MA: Addison-Wesley Publishing Co., 1978.

D. Slaby, Steve M. *Fundamentals of Three Dimensional Descriptive Geometry.* 2nd ed. New York: John Wiley and Sons, Inc., 1976.

SHEET METAL DEVELOPMENTS
UNIT X

INFORMATION SHEET

I. Terms and definitions

A. True length of a line--The exact measurable view of the exact length of a line found by observation, projection, or calculation

B. True size of a surface--The exact measurable view of the exact size of a surface found by observation, projection, or calculation

C. Development--A pattern of the true sizes of unfolded or unrolled surfaces arranged to be folded to the desired shape

D. Bend allowance (BA)--An additional amount of material necessary when making a bend

(NOTE: Usually BA is calculated for material over .65 mm.)

E. Radial line development--The development of objects that can be developed due to elements radiating from a single point or vertex

Examples: Cones, pyramids

F. Parallel line development--The development of objects that can be developed due to parallel elements on these surfaces

Examples: Cylinders, prisms

G. Triangulation--A method of developing surfaces not possible by the parallel line or radial line methods

Examples: Transition pieces, hoppers

H. Warped surface--A ruled surface that cannot be developed

Examples: Oblique helicoid, cylindroid, many exterior surfaces on an airplane, approximation developments are possible

I. Right section--A cutting plane perpendicular to an axis of a three dimensional form

(NOTE: The axis may be the center line of a cylinder, cone, or true lengths of a prism, square, or hexagon shape.)

J. True length diagram--A diagram of the true lengths projected from the normal views

K. Elements of a surface--Ruled lines on the surface of geometric shapes

L. Single curved surface--A ruled surface generated by a straight line that can be developed

INFORMATION SHEET

M. Double curved surface--A surface which has no straight line elements and cannot be developed

Examples: Sphere, cone, paraboloid, hyperboloid, approximation developments are possible

N. Ruled surface--Any surface generated by straight lines

(NOTE: This may be a plane, single curved surface, or a warped surface.)

O. Conic section--The intersection of a circular cone and a plane

P. Stretch out line--A line that is perpendicular to each element on which a parallel line development is unrolled or unfolded

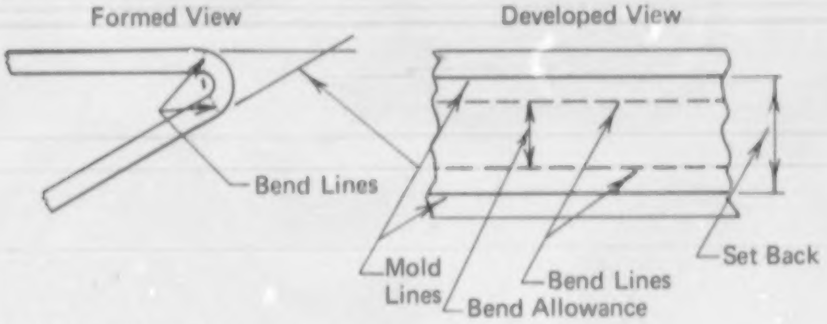
Q. Transition piece--A piece that connects two differently shaped conductors

R. Master layouts--Original and complete developments of parts used for reference and checking

S. Contour templates--Templates to exact contour of part used for checking parts at production stages

T. Shrink templates--Contour templates made with a shrink scale for die maker and foundry

U. Bend line--Where bend starts



V. Mold line (ML)--The intersection of two adjacent surfaces

(NOTE: Inside surface intersections are called "inside mold lines" [IML] and outside surface intersections are called "outside mold lines" [OML].)

W. Relief holes--Drilled or routed holes at intersection of bends to relieve strain which would cause metal to crack or buckle

X. Rotation--A method of projection in which the observer stays stationary and the object is rotated for different views of the object

INFORMATION SHEET

Y. Folding line--A reference line normally between two views representing the edge of a plane of projection

II. Visualization of near and far points and planes (Transparencies 1, 2, and 3)

A. Near points and planes (Transparency 1)

1. Top view--Points or planes are near you when they are observed in the front view closest to line of sight (LOS)

2. Front view--Points or planes are near you when they are observed in the top or side view closest to the line of sight (LOS)

3. Side view--Points or planes are near you when they are observed in the front view closest to the line of sight (LOS)

B. Far points and planes (Transparency 1)

1. Top view--Points or planes are far from you when they are observed in the front view far away from or on the other side of the line of sight

2. Front view--Points or planes are far from you when they are observed in the top or side view far away from or on the other side of the line of sight

3. Side view--Points or planes are far from you when they are observed in the front view far away from or on the other side of the line of sight

C. Points are observed when: (Transparency 2)

1. Line of sight is parallel to a true length line

2. Two lines intersect

D. Planes are observed when: (Transparency 2)

1. Line of sight is perpendicular to an edge view in which case the observed plane is in true size

2. Line of sight is inclined to edge view in which case the surface is not in true size

(NOTE: In principal views, the surface is inclined if LOS is inclined to the edge view.)

3. Line of sight is oblique to edge view in which case the surface is not in true size

(NOTE: In principal views, the surface is oblique if an edge view of the plane is not observed. In other words, the plane appears not in true size in all of the principal planes, and no edge view is observed.)

INFORMATION SHEET

E. Label points, lines, and planes (Transparency 3)

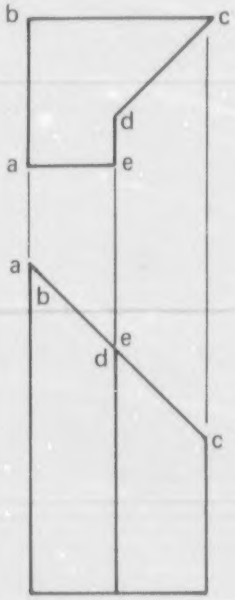
   1. Use lower case letters for points

   2. Use T for top, F for front, and S for side view

III. Steps for constructing an auxiliary view (Transparency 4)

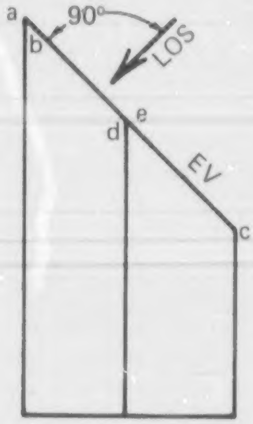
   A. Label points of entire object or certain lines or certain planes where an auxiliary view is needed

   Example: Find TS of plane abcde



   B. Select line of sight to get desired view

   Example: Line of sight is perpendicular to edge view of plane abcde that is to be drawn true size

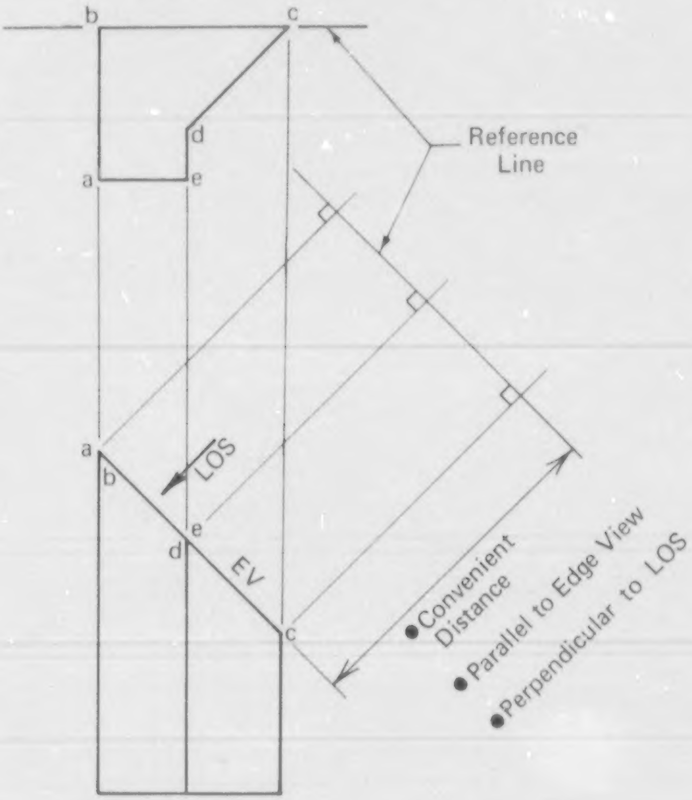


INFORMATION SHEET

C. Locate reference or folding line in the adjacent view in either of the following places--back, middle, front, or between views

(NOTE: When line is between views, it is called a folding line. When line is on the object, it is called a reference line.)

Example: The back is selected in the top view


b
c
d
a
e
Reference Line
a
b
LOS
e
d
EV
c
●Convenient Distance
●Parallel to Edge View
●Perpendicular to LOS

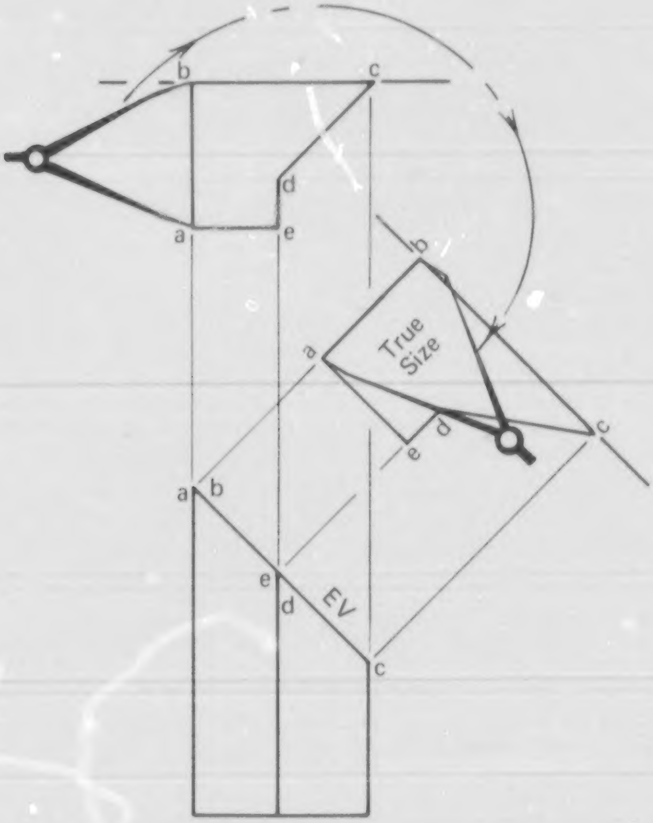
D. Draw reference or folding line in auxiliary view perpendicular to line of sight at an adequate distance from edge of front view

INFORMATION SHEET

E. Draw light projection lines from the points of the view parallel to the line of sight

(NOTE: Projection lines will be perpendicular to reference line.)

Example: Draw projection lines



F. Transfer distances from adjacent view in relation to reference plane using dividers

Example: Transfer points a, e, d. Since b and c are on reference line, mark the points on the reference line

G. Connect points in auxiliary view that are connected in adjacent view; darken lines

Example: Connect points abcde and back to a

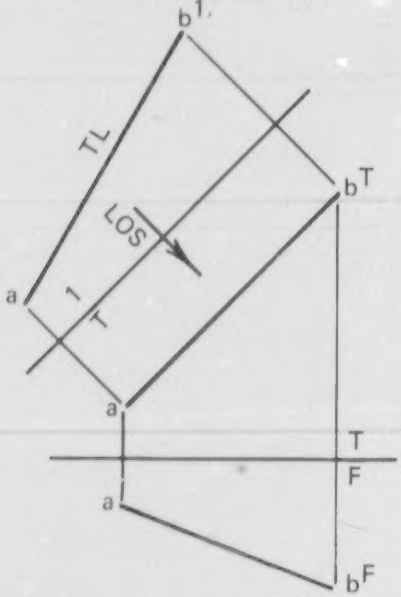
(NOTE: Notice the similar shape of the surface has 5 lines in the top view and 5 lines in the auxiliary view.)

INFORMATION SHEET

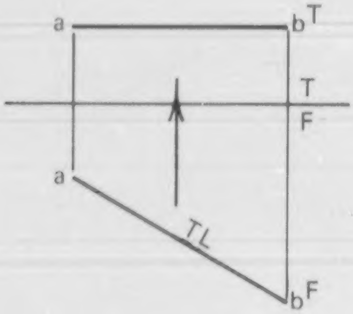
IV. True length lines and true size planes (Transparencies 5, 6, and 7)

A. True length lines are observed when: (Transparencies 5 and 6)

1. The line of sight is perpendicular to a line--an oblique line

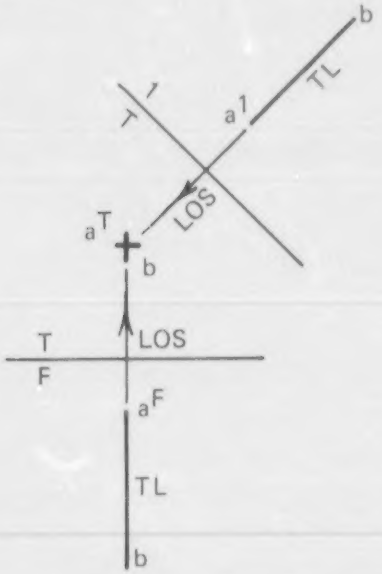


2. The folding line is parallel to a line and line of sight is perpendicular to line--an inclined line

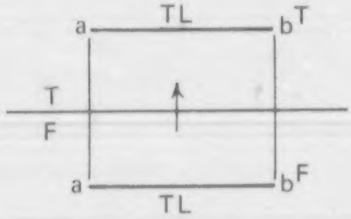


INFORMATION SHEET

3. The line of sight points to the point view of a line


b
TL
a1
T
1
LOS
aT
b
LOS
T
F
aF
TL
b

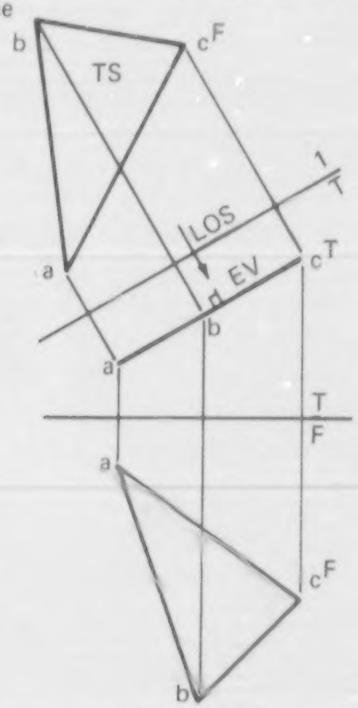
4. Both lines are parallel to the folding line--a normal line


a
TL
bT
T
F
a
TL
bF

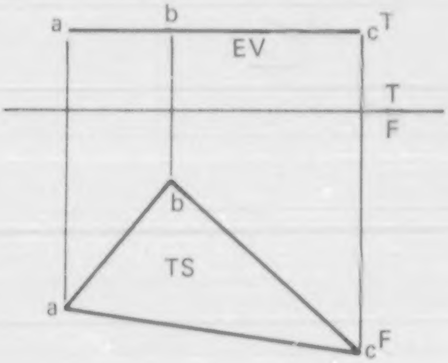
INFORMATION SHEET

B. True size of a plane is observed when: (Transparencies 7 and 8)

1. The line of sight is perpendicular to the edge view of the plane--an inclined plane


b
c^F
TS
1
T
LOS
EV
c^T
a
d
b
a
T
F
a
c^F
b

2. The folding line is parallel to an edge view--a normal plane

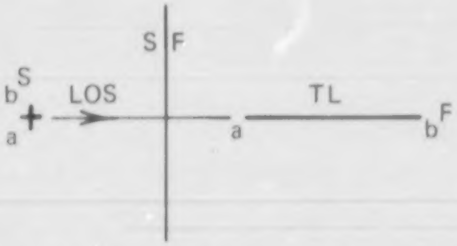

a
b
c^T
EV
T
F
b
TS
a
c^F

INFORMATION SHEET

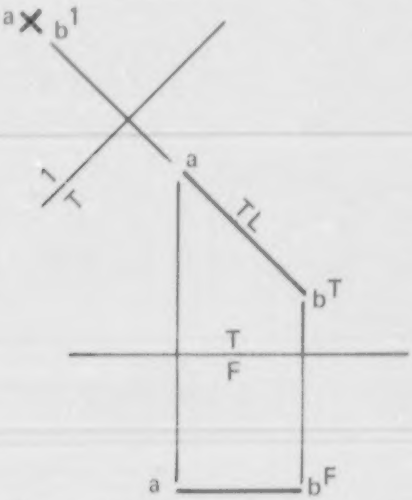
V. Point views of lines and edge views of planes (Transparencies 9 and 10)

  A. Point views (PV) of lines are observed when: (Transparency 9)

    1. The line of sight is parallel to true length (TL) lines

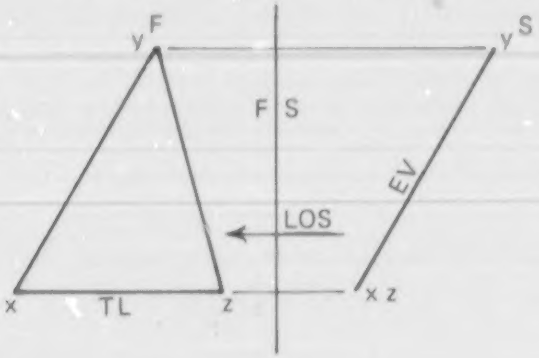

S | F
b^S
LOS
TL
a
a
b^F

    2. The folding line is perpendicular to the true length line


a
b^1
1
T
a
TL
b^T
T
F
a
b^F

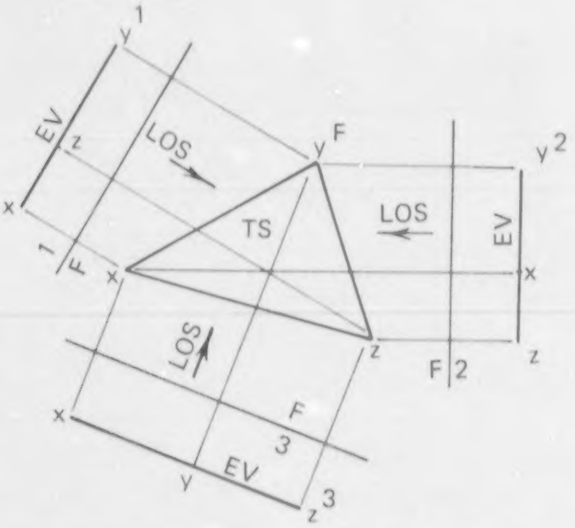
  B. Edge views (EV) of planes are observed when: (Transparency 10)

    1. The line of sight is parallel to a true length line in the plane


y^F
F | S
y^S
EV
LOS
x
TL
z
x z

INFORMATION SHEET

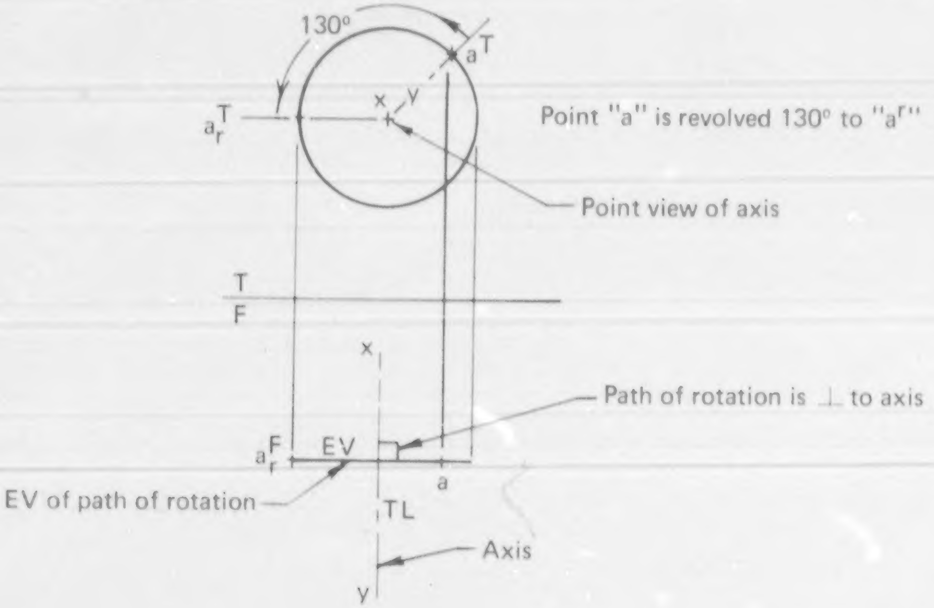
2. The line of sight points to any view of a true size plane, and the results will be edge views


y 1
EV
z
LOS
x
1
F
x
y F
TS
LOS
y 2
EV
x
LOS
z
F 2
z
x
F
3
y
EV
z 3

VI. Rotation characteristics (Transparencies 11, 12, and 13)

(NOTE: Rotation is an easier way to find TL and TS.)

A. The path of rotation of any point not on the axis appears as a circle in a view showing the axis of rotation as a point


130°
a^T
x
y
a_r^T
Point view of axis
T
F
x
Path of rotation is ⊥ to axis
a_r^F
EV
a
EV of path of rotation
TL
Axis
y

Point "a" is revolved 130° to "a^r"

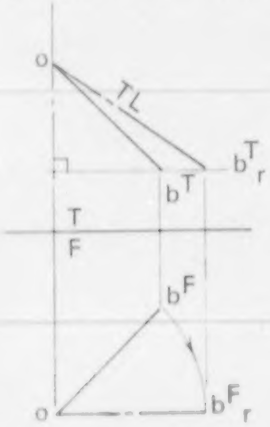
INFORMATION SHEET

B. The plane of the path of rotation of any point appears in edge view (EV) and perpendicular to the axis in a view showing the axis of rotaton in true length

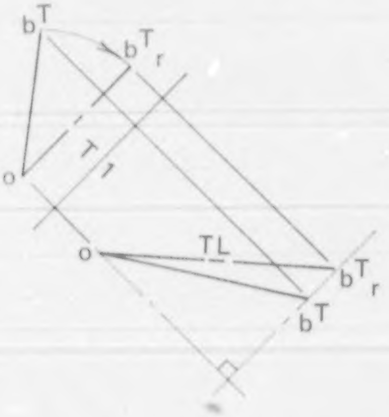
C. True lengths by rotation (Transparency 12)

1. A line may be rotated until it is parallel to a principal plane

2. The line is projected onto the adjacent plane



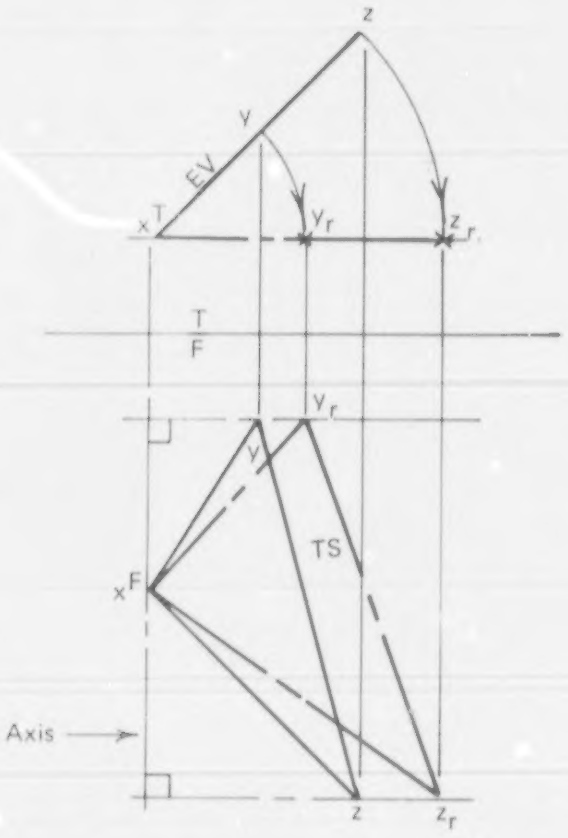
3. Since it is parallel to the folding line, it is in true length in the adjacent plane



INFORMATION SHEET

D. True sizes by rotation (Transparency 13)

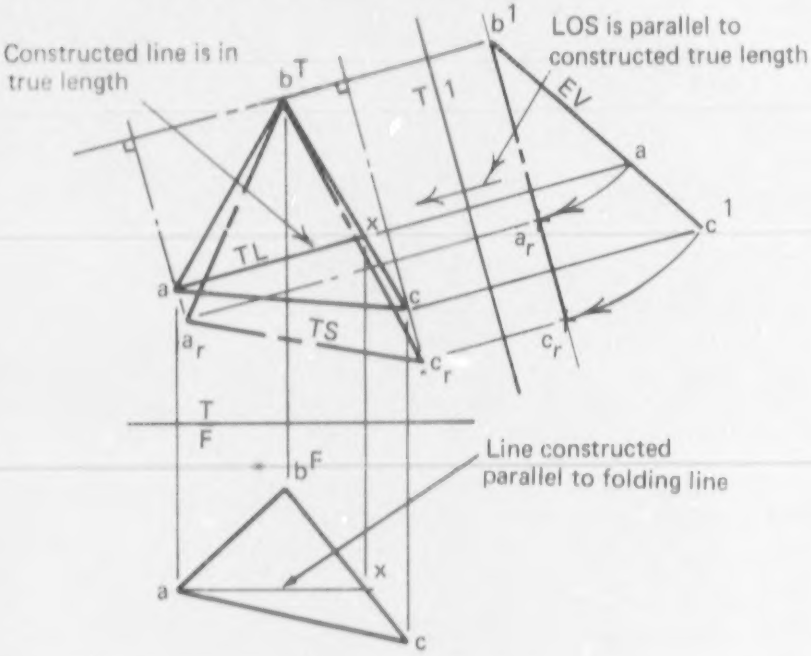
1. An edge view may be rotated until it is parallel to an orthographic plane


z
y
EV
x T
y r
z r
T
F
y r
y
TS
x F
Axis
z
z r

INFORMATION SHEET

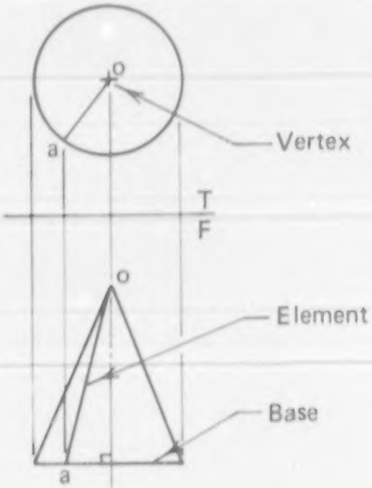
2. The edge view is then projected onto the plane and is in true size

(NOTE: In this example, edge view is found by constructing horizontal line ax in front view and projecting TL line in top view.)


Constructed line is in true length
LOS is parallel to constructed true length
b1
bT
T 1
EV
a
c1
x
TL
a
c
ar
ar
TS
cr
cr
T
F
bF
Line constructed parallel to folding line
a
x
c

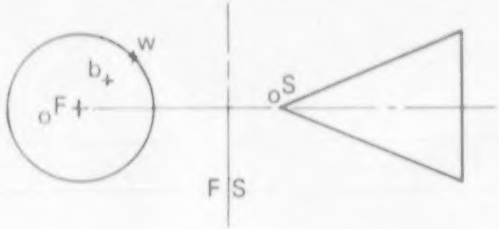
VII. Elements of single curved surfaces (Transparency 14)

A. Cones--Vertex to base

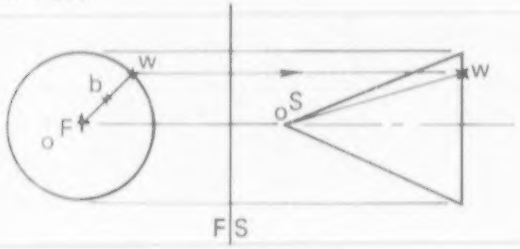

o
a
Vertex
T
F
o
Element
Base
a

INFORMATION SHEET

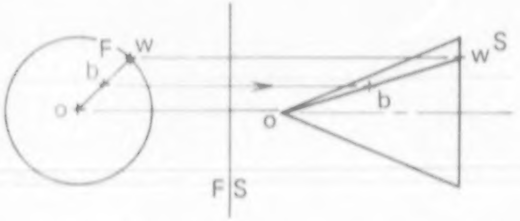
Example: Locate point b on surface of cone in side view



1. Project from vertex O^F through b to base of cone point W to make element OW^F

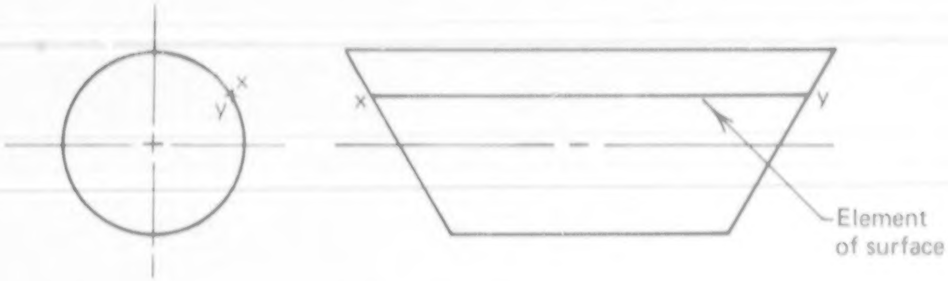


2. Project point W to side view to base of cone W^S and connect O^S to W^S to make element OW^S


F w
b
o
w S
b
o
F | S

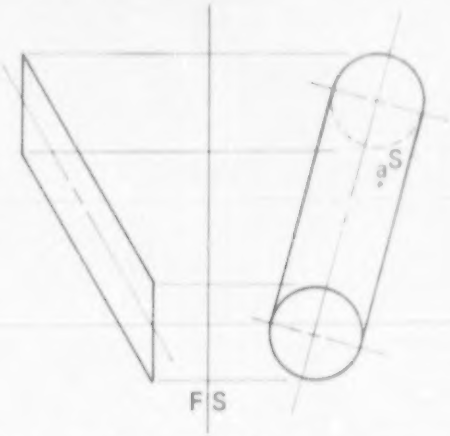
3. Project point b^F to find answer at element OW^S

B. Cylinders--Parallel to center

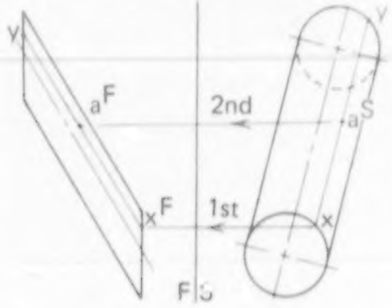

x
y
x
y
Element of surface

INFORMATION SHEET

Example: Locate point "a" on surface of cylinder



1. Project element xy through "a" intersecting circles in side view



2. Project intersection of X and Y to adjacent edge view of circles and connect to form element in front view

   (NOTE: One line is all that is necessary because element is parallel to center of cylinder.)

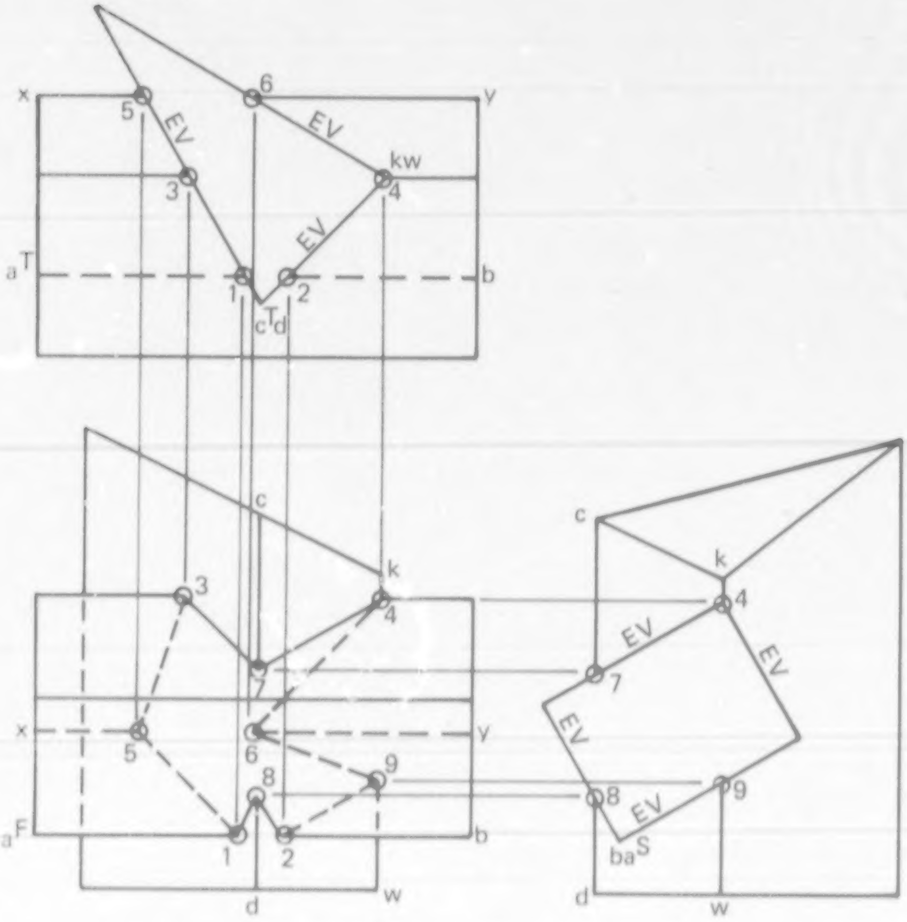
3. Project point "a^S from side view" to find answer to problem at element XY^F in front view

INFORMATION SHEET

VIII. Methods for finding intersections of surfaces

A. Edge view given (Transparency 15)

Example:


x
5
6
EV
EV
y
kw
3
4
EV
a T
b
1
2
c T d
c
k
3
4
7
x
5
6
y
9
8
a F
1
2
b
d
w
c
k
4
EV
EV
7
EV
8
9
EV
ba S
d
w

1. When edge views are given, existing piercing points can be readily located and projected

2. Visibility requires logical thinking of the position of the line of sight and what is near the observer and what is far from the observer

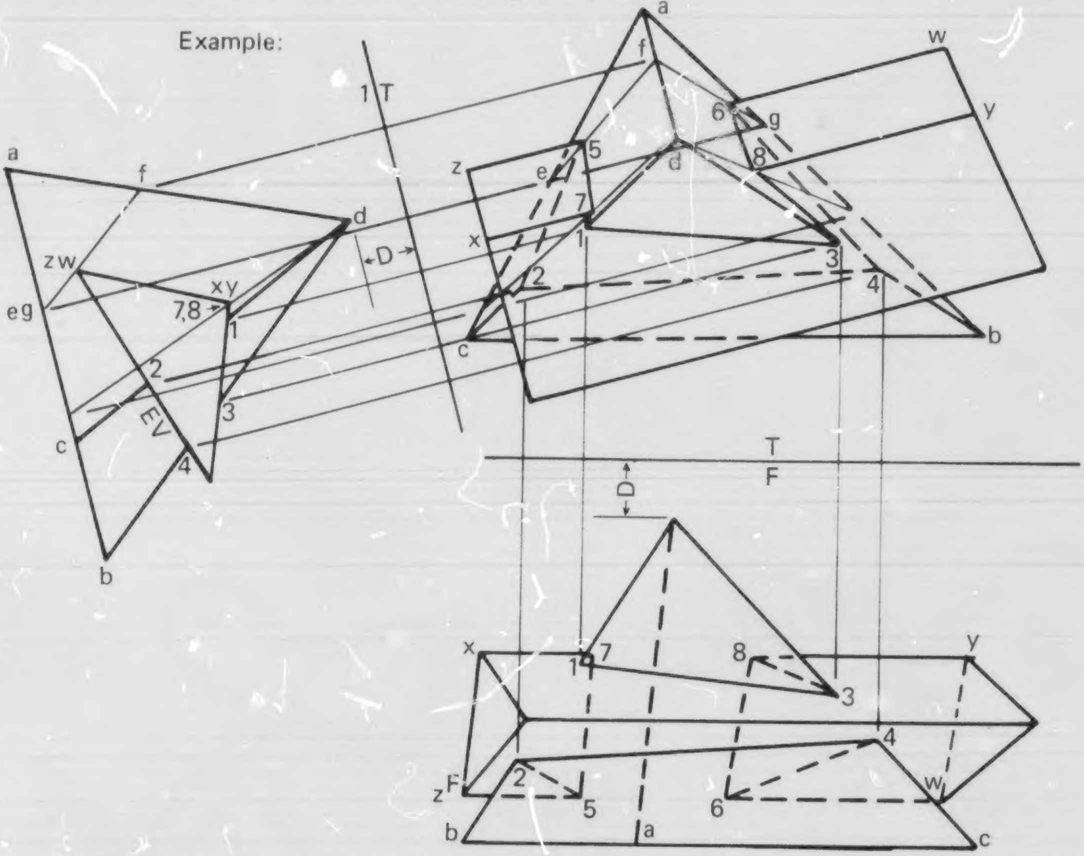
3. Points 5 and 6 can be observed in top view where line xy intersects the two edge views

4. Points 8 and 9 can be observed in the side view where the edges of the planes are intersected by cd and kw

INFORMATION SHEET

B. Auxiliary view method (Transparency 16)

Example:


a
f
w
1 T
6
g
y
z
e
5
d
7
a
f
d
x
D
1
3
zw
xy
2
4
eg
7,8
1
b
c
2
3
EV
c
4
T
F
D
b
x
1
7
8
y
3
4
zF
2
5
6
w
b
a
c

1. Construct an auxiliary view to give edges of surfaces
   a. Line zw is in TL in top view
   b. LOS is parallel to TL to give edge views of the planes in the auxiliary view

2. When edges are constructed, piercing points may be readily located and projected

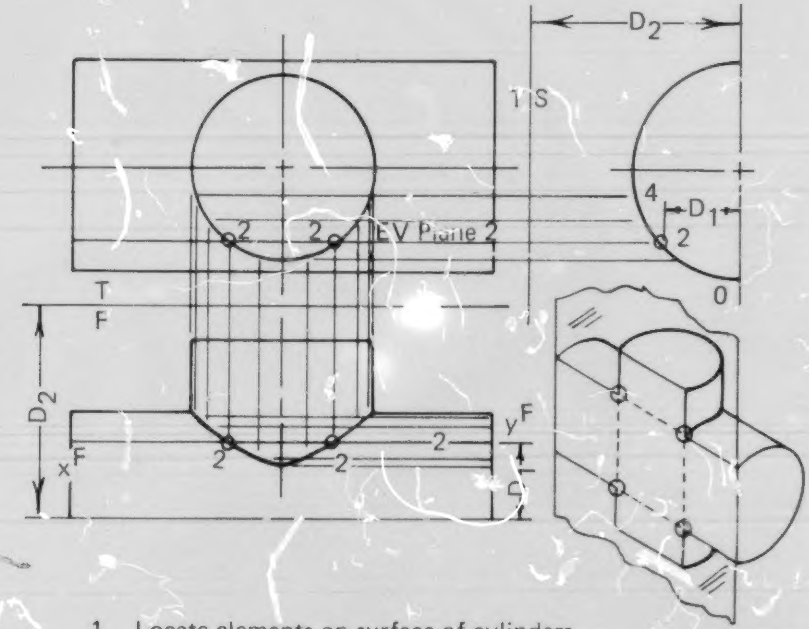
   (NOTE: The two view method can be used to find additional piercing points.)

3. The two view method of piercing points is used to find where line zw and line xy intersect the planes adc and adb

4. Visibility requires logical thinking of the position of the line of sight and what is near the observer and what is far from the observer

INFORMATION SHEET

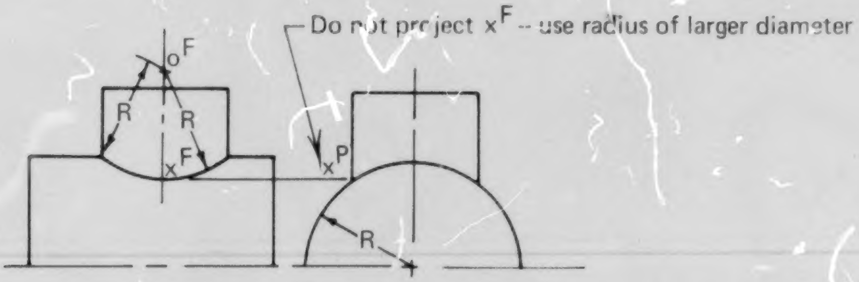
C. Cylinders intersecting (Transparency 17)


D2
TS
4
D1
2
2
2
EV Plane 2
T
F
0
D2
yF
xF
2
2
2
2

1. Locate elements on surface of cylinders
2. Find their intersection
3. Use correct visibility

D. Approximate intersections

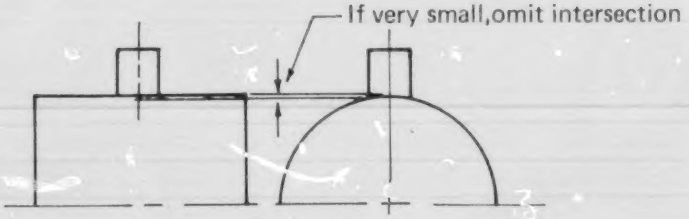
1. Large diameters--Use radius of larger cylinder



Do not project x^F -- use radius of larger diameter

INFORMATION SHEET

2. Small diameters--Ignore intersection


If very small,omit intersection

IX. General groups of developments (Transparency 18)

A. Radial line (Transparencies 19 and 20)

Example: Cone, pyramids

B. Parallel line (Transparencies 21 and 22)

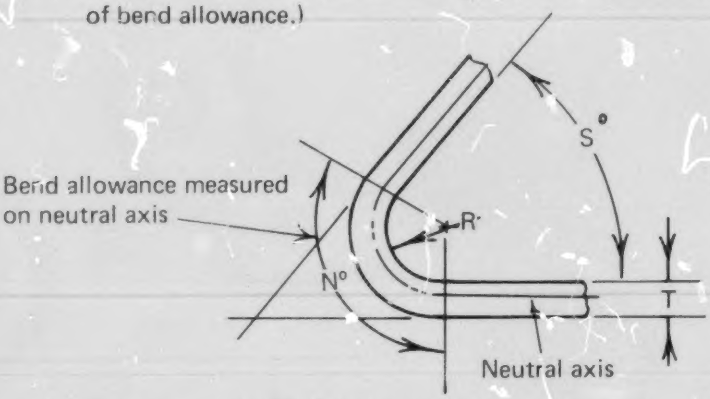
Example: Cylinders, prisms

C. Triangulation (Transparency 23)

Example: Transition pieces, hoppers

X. Bend allowance calculation

(NOTE: Refer to "Manufacturing Processes", Unit IX of this book for a review of bend allowance.)


S°
Bend allowance measured on neutral axis
R
N°
T
Neutral axis

A. Calculate for materials thicker than .65 mm

INFORMATION SHEET

B. Use formula:

$BA = (.017453R + .0078T)N$

BA = Bend allowance
R = Radius of bend IML
T = Metal thickness
N = Number of degrees of bend

Example: Radius = .75"
Thickness = .25"
Number of degrees = 130°

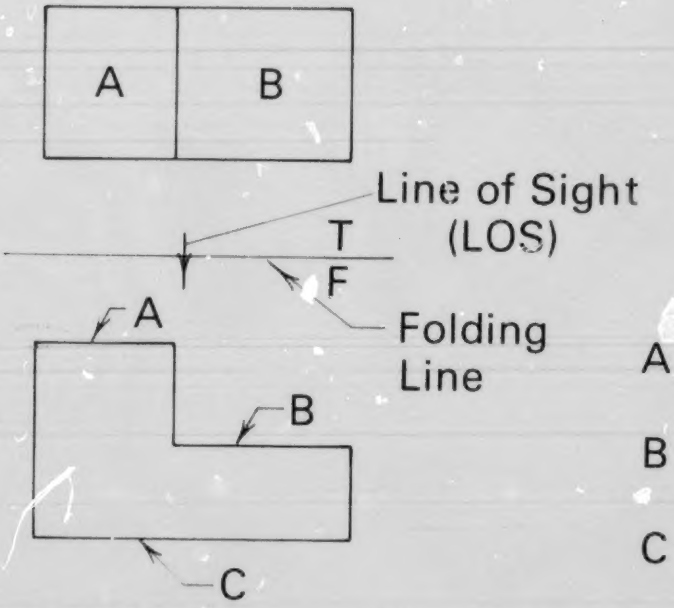
$BA = (0.17453R + .0078T)N$

$BA = .017453(.75) + .0078(.25)(130^{\circ})$

$BA = \underline{1.96''}$

Near and Far Points and Planes

(Observer Looking Down On Top View)

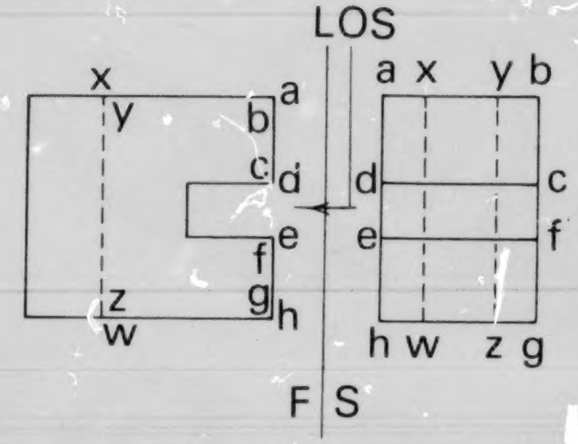

A
B
Line of Sight
(LOS)
T
F
Folding
Line
A
B
C

A -- Near observer

B -- Near observer

C -- Far from observer

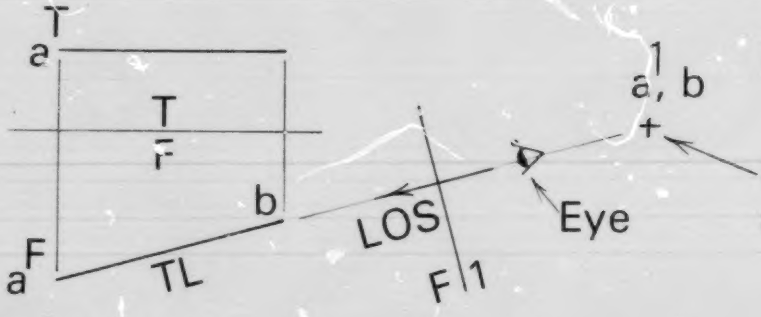
(Observer Looking On Right Side of Object)


LOS
x
y
a
b
c
d
e
f
g
h
z
w
a x y b
d c
e f
h w z g
F S

Points a b c d e f g h
are near observer

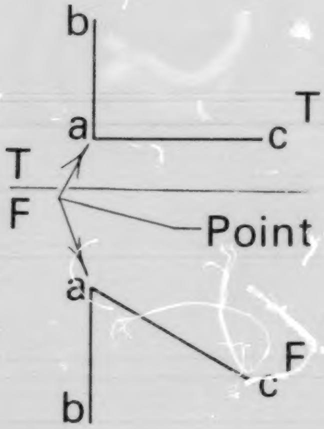
Points x y z w
are far from observer

Observing Points and Planes

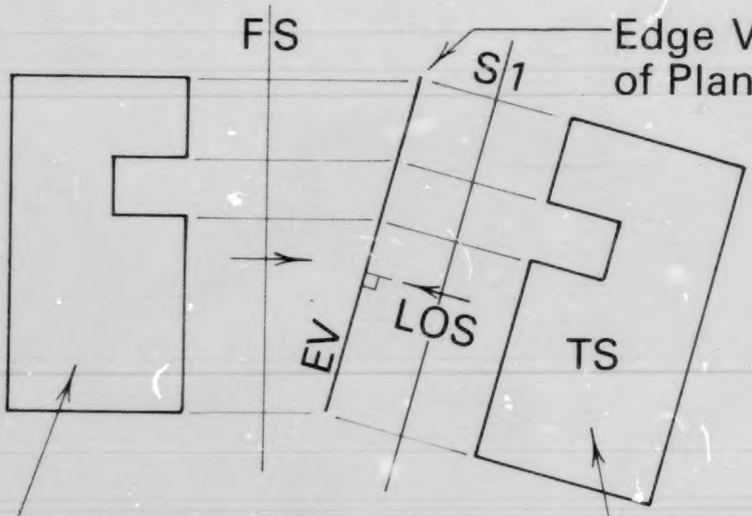

T
a
T
F
b
F
a
TL
LOS
F
1
1
a, b
Eye

Point View (a)

Point is what you see of a line


b
a
c
T
T
F
Point
a
F
c
b

Point View (b)
as a Corner of an Object


F
S
S
1
EV
LOS
TS

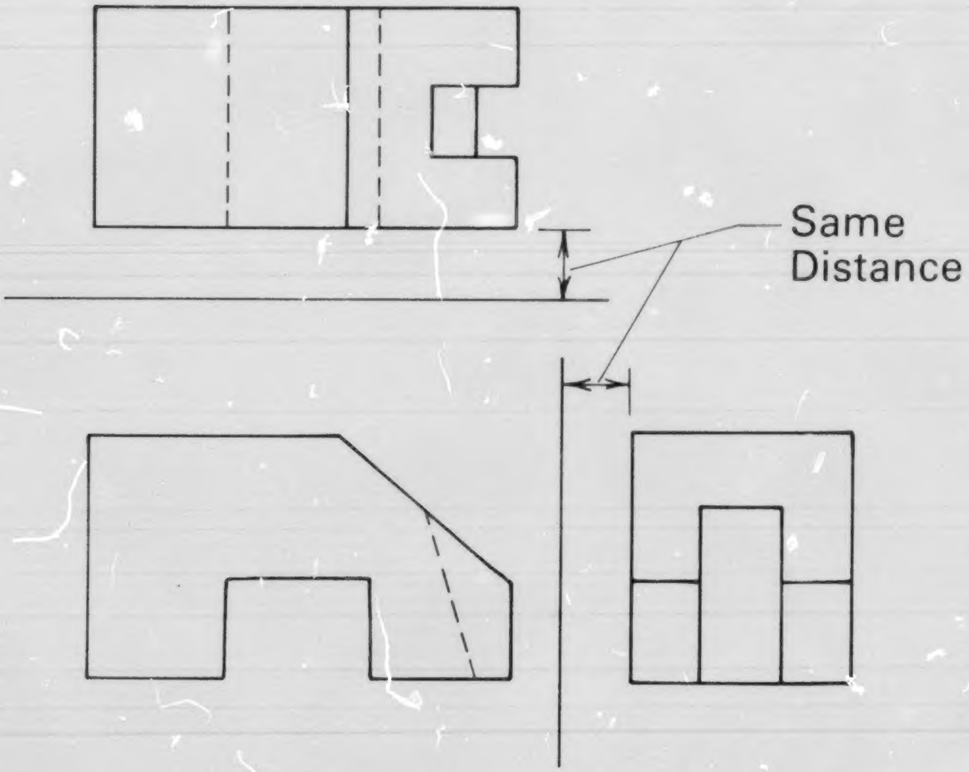
Edge View (EV)
of Plane

Planes

Not True Size

True Size Plane

Labeling Points, Lines, and Planes

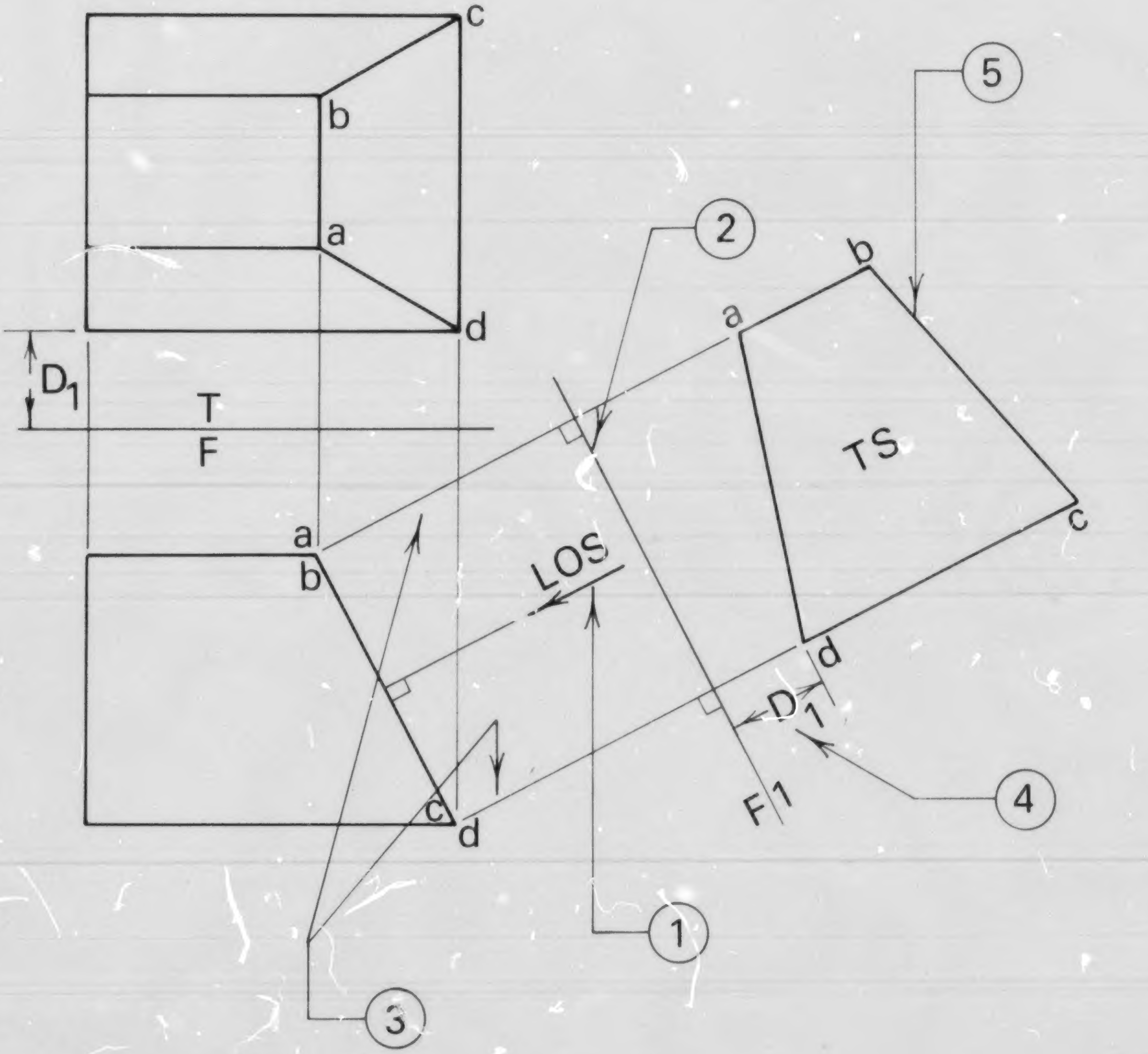


(NOTE: The labeling of points, lines, and planes on this transparency are meant to be supplied by the instructor.)

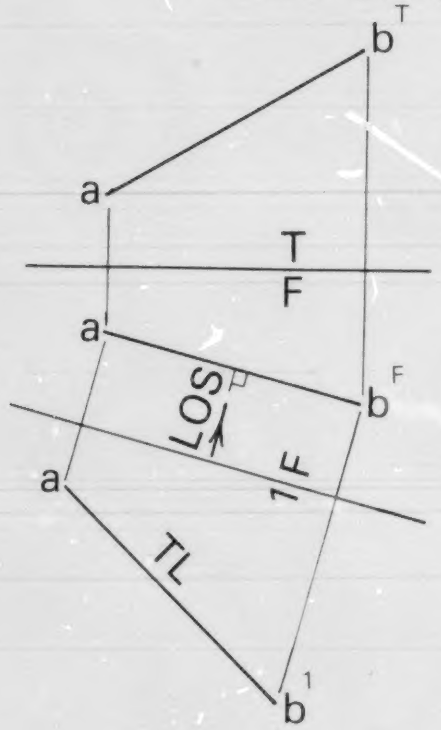
Steps for Constructing Auxiliary Views

Folding Line Method

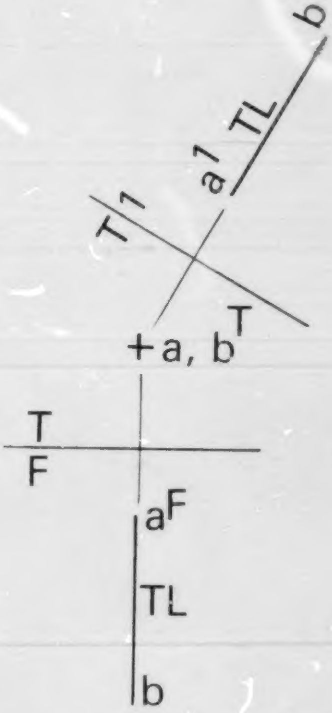
1. Line of Sight--LOS
2. Folding Line-- ⊥ to LOS
3. Project ⊥ to Folding Line
4. Transfer Distances
5. Complete the View

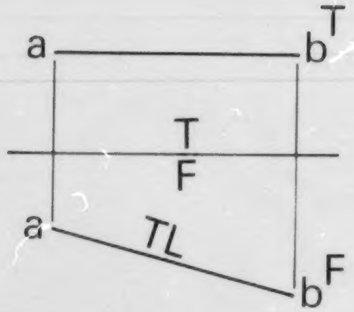

c
b
a
d
D_1
T
F
a
b
c
d
LOS
①
②
③
④
⑤
a
b
c
d
TS
D_1
F1

True Lengths of Lines


b
T
a
T
F
a
LOS
b
F
1F
a
TL
1
b

From Line of
Sight Being
⊥ to Line

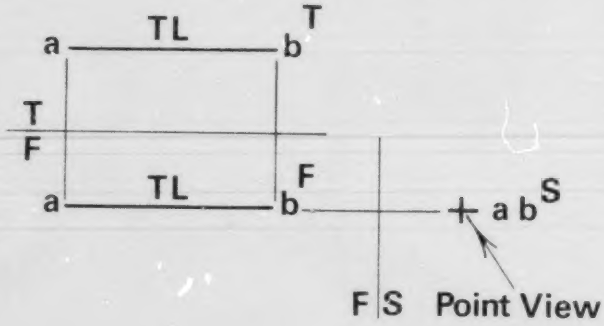

b
TL
a1
T/1
+a, b
T
T
F
a
F
TL
b


a
b
T
T
F
a
TL
b
F

From Folding
Line Being Parallel to Line

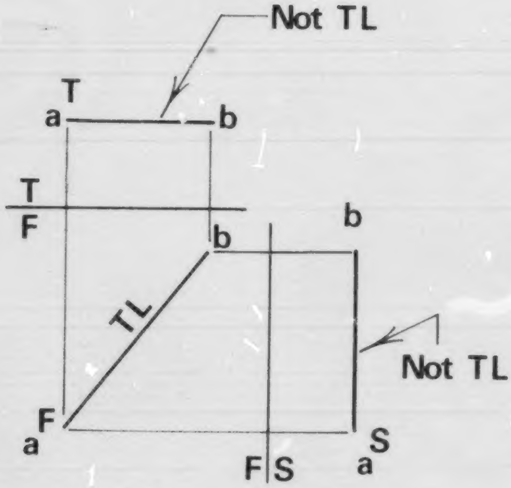
From Point
View

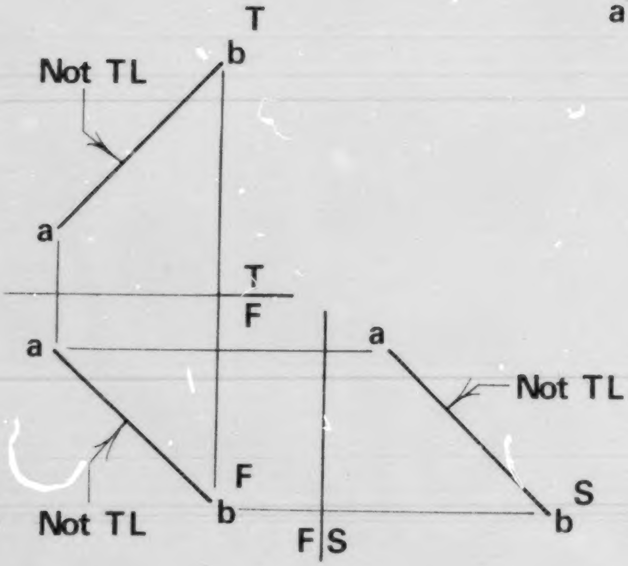
Identifying True Lengths


a
TL
b
T
T
F
a
TL
b
F
a b
S
F|S
Point View

Normal Line

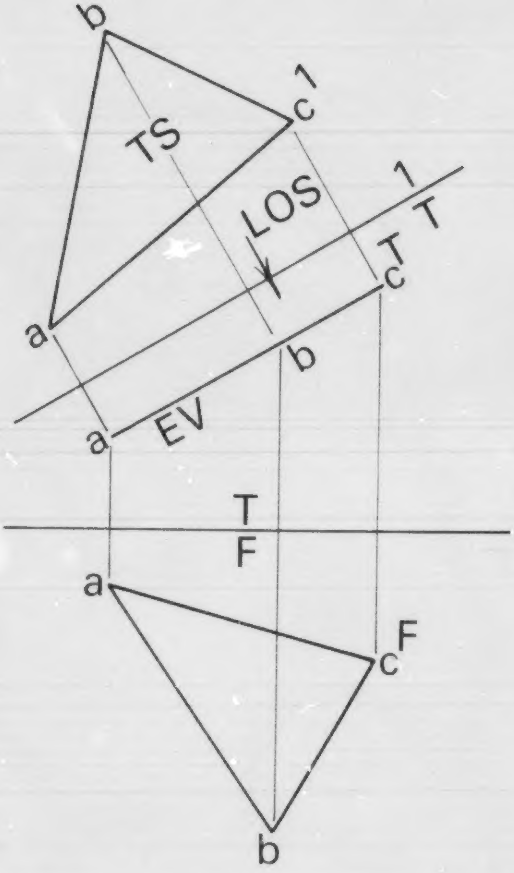
Inclined Line


Not TL
T
a
b
T
F
b
b
TL
Not TL
F
a
F|S
S
a

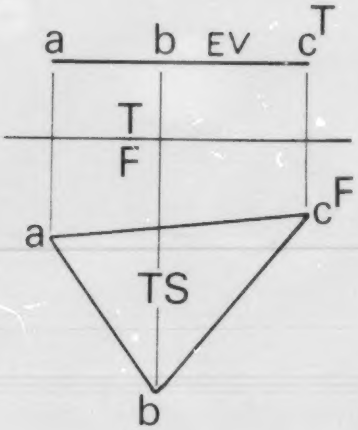

T
b
Not TL
a
T
F
a
a
Not TL
F
Not TL
b
F|S
S
b

Oblique Line

Observing True Size Planes

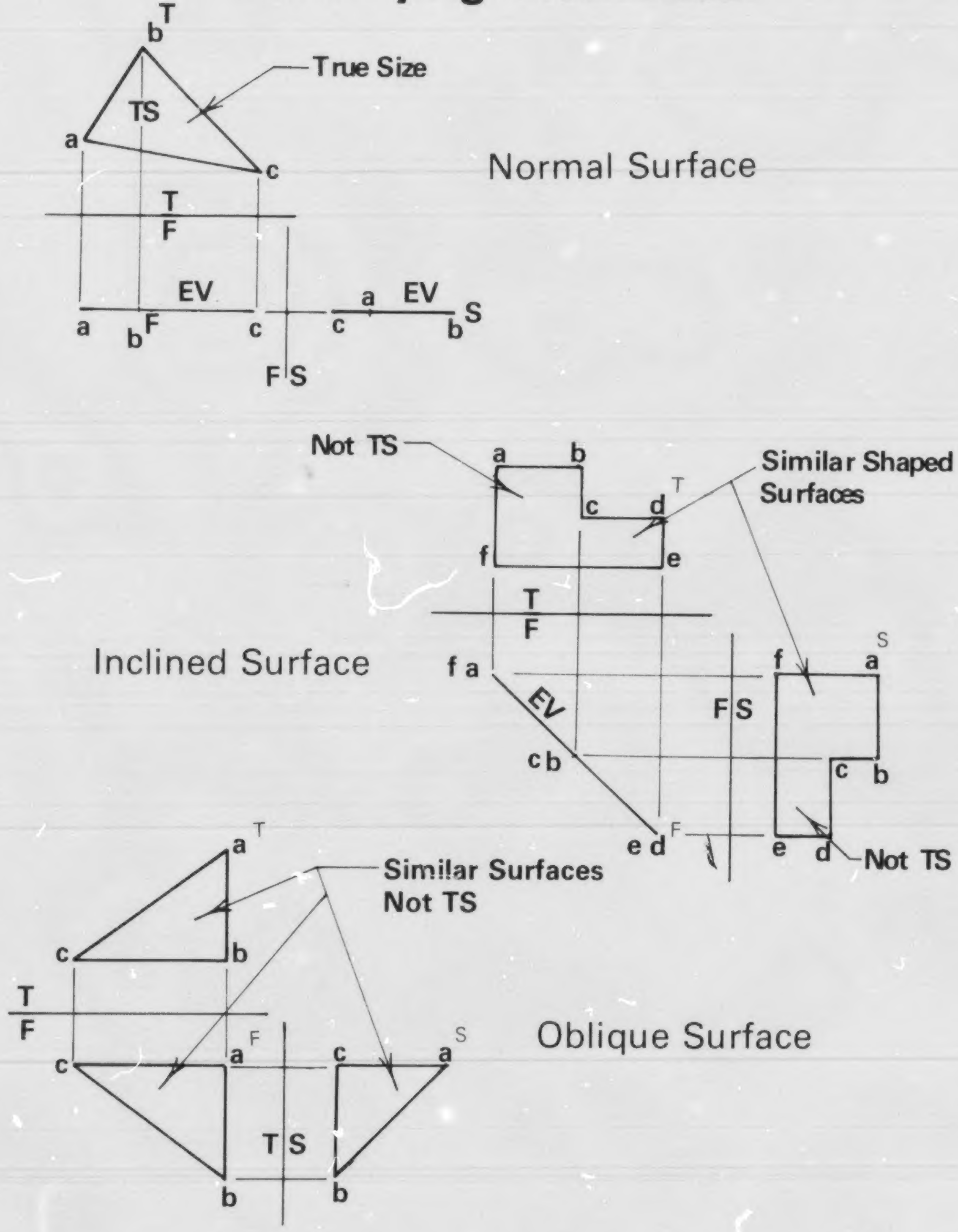

b
c1
TS
LOS
1
T
cT
a
b
a
EV
T
F
a
cF
b

Line of
Sight ⊥
To Edge
View


a
b
EV
cT
T
F
a
cF
TS
b

Folding Line
Parallel to
Edge View

Identifying True Sizes

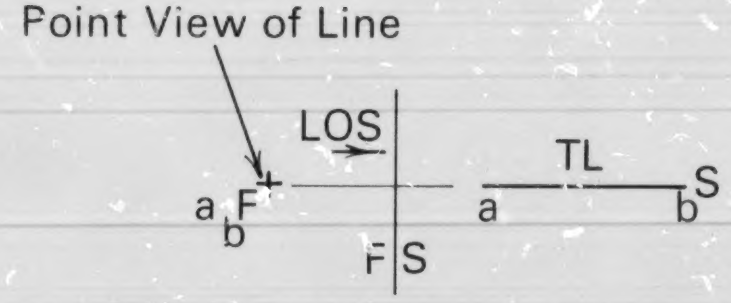

b T
True Size
TS
a
c
T
F
EV
a
b F
c
c
a
EV
b S
F S
Not TS
a
b
c
d T
Similar Shaped Surfaces
f
e
T
F
f a
EV
c b
e d F
F S
f
a S
c
b
e
d
Not TS
a T
Similar Surfaces Not TS
c
b
T
F
c
a F
c
a S
T S
b
b

Normal Surface

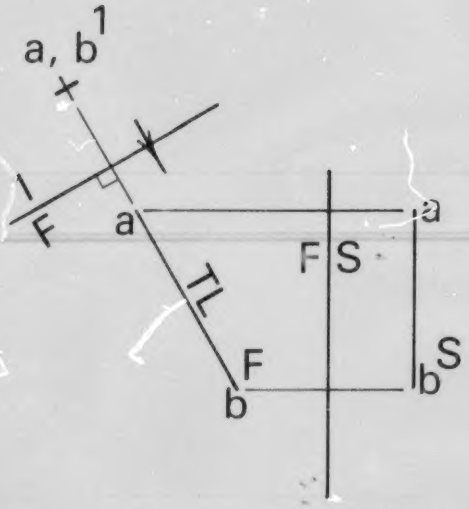
Inclined Surface

Oblique Surface

Point Views of Lines

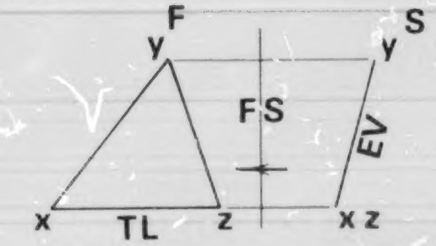

Point View of Line
LOS
a
b
F
F
S
TL
a
b
S

LOS Parallel to TL Line


a, b
1
1
F
a
TL
F
b
F
S
a
b
S

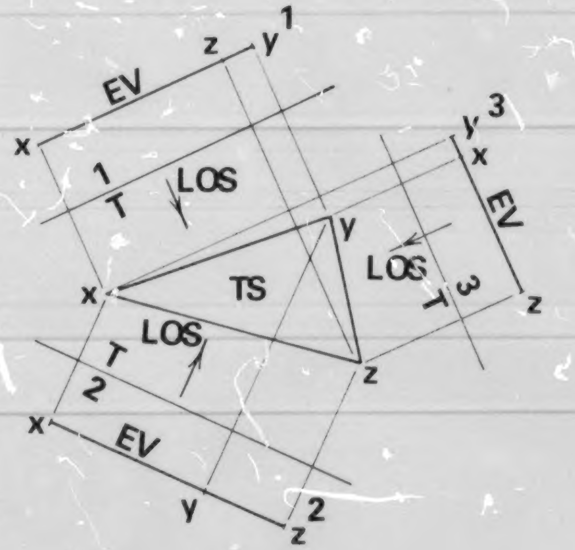
Folding Line ⊥ to TL Line

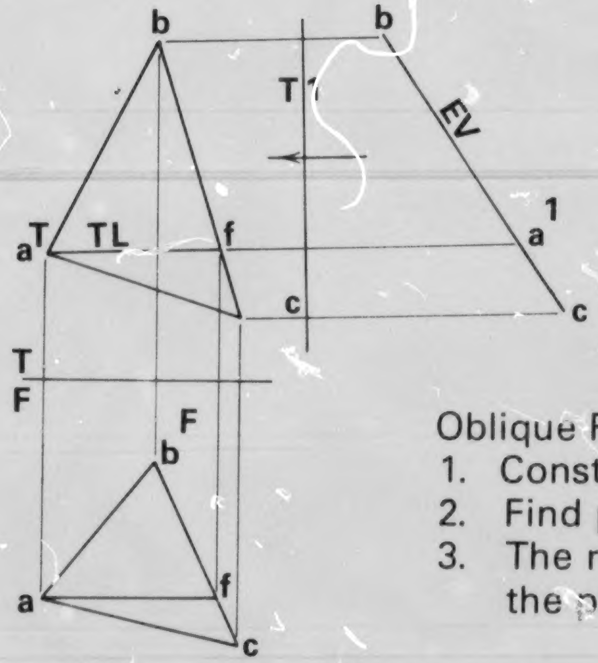
Edge Views of Planes


F
S
y
y
FS
EV
x
TL
z
x z

LOS Parallel to TL Line
in the Plane

LOS Pointing to any
View of TS Plane Will
Give an Edge View

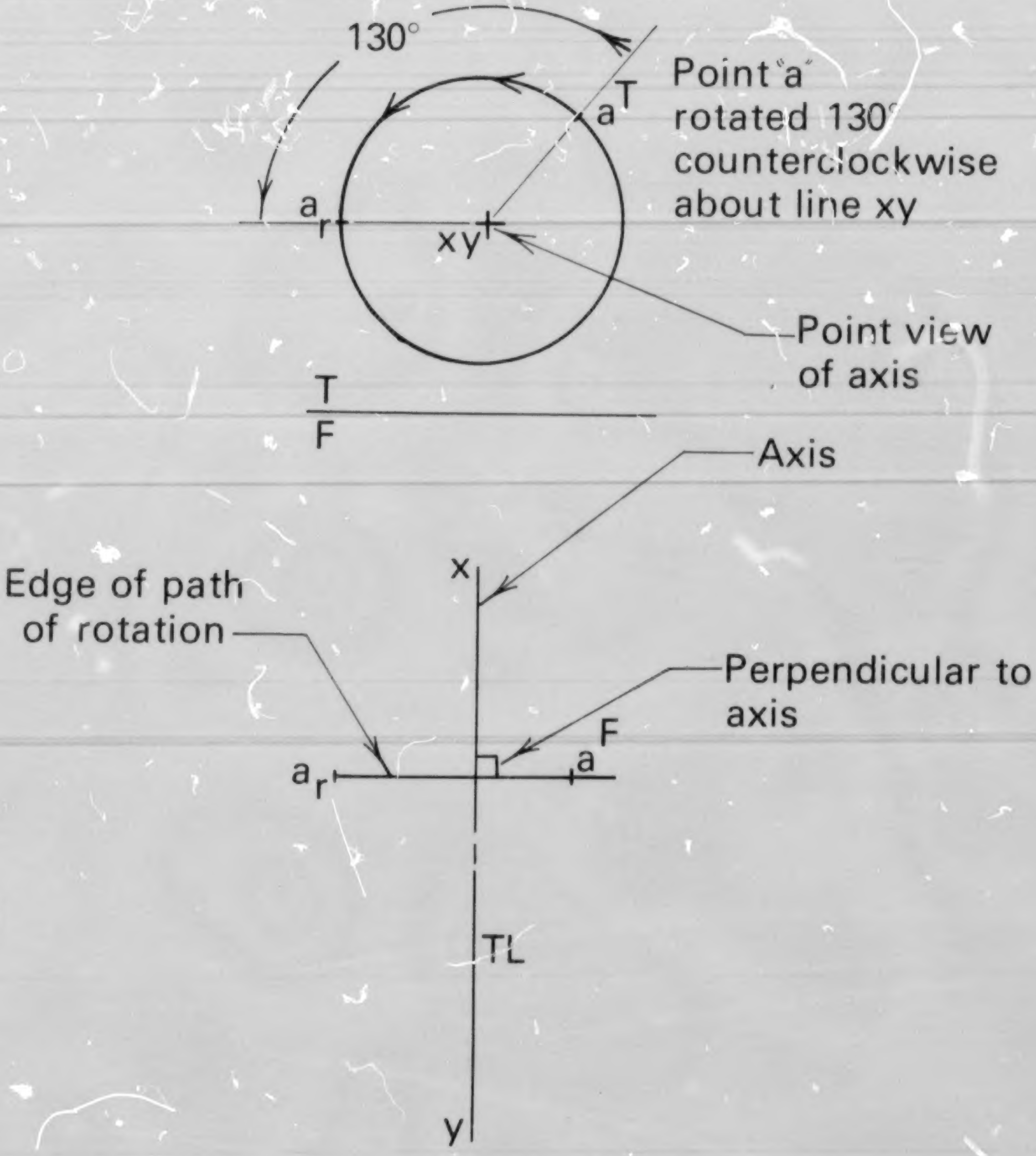

z
y
1
EV
x
1
T
LOS
y
3
x
EV
y
x
TS
LOS
3
T
z
LOS
T
2
z
x
EV
y
2
z


b
b
T
1
EV
a
1
a
T
TL
f
c
c
T
F
F
b
a
f
c

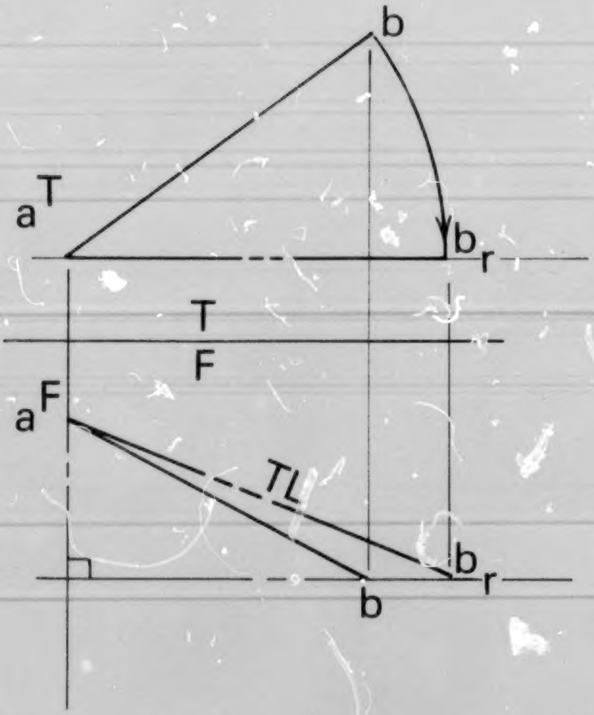
Oblique Plane

1. Construct TL line af in one view.
2. Find point view of TL line.
3. The result is an edge view of the plane.

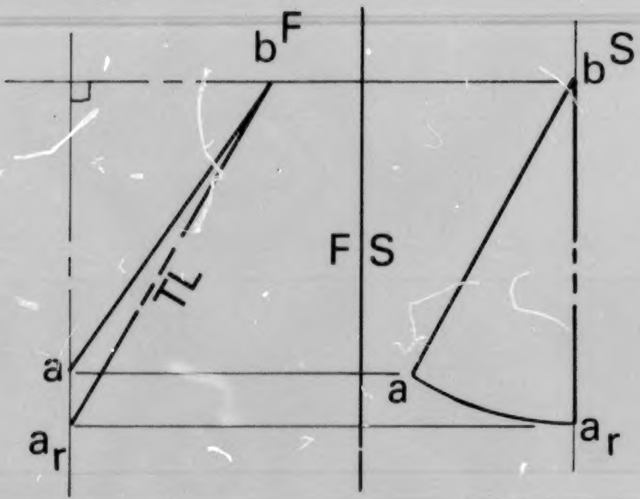
Rotation of a Point


130°
Point "a" rotated 130° counterclockwise about line xy
a^T
a_r
xy
Point view of axis
T
F
Axis
x
Edge of path of rotation
Perpendicular to axis
a^F
a_r
TL
y

True Lengths by Rotation

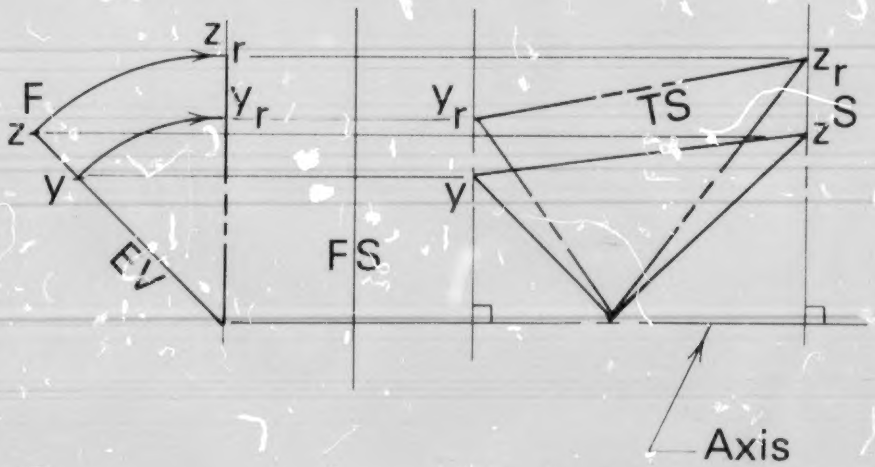

b
a^T
b$_r$
T
F
a^F
TL
b$_r$
b

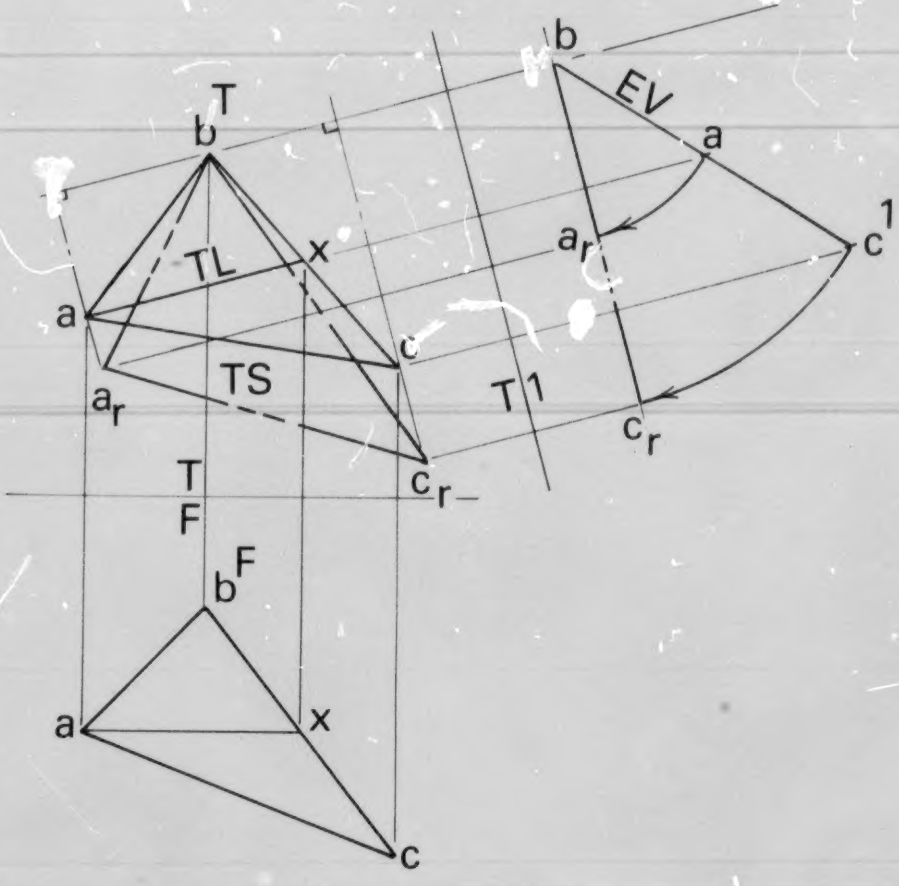
(a)


b^F
b^S
TL
F
S
a
a
a$_r$
a$_r$

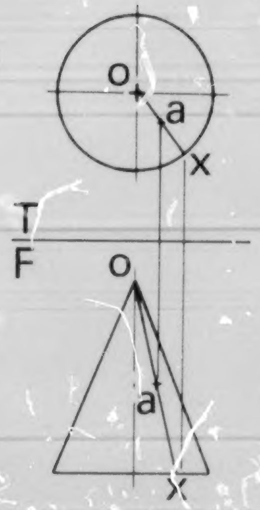
(b)

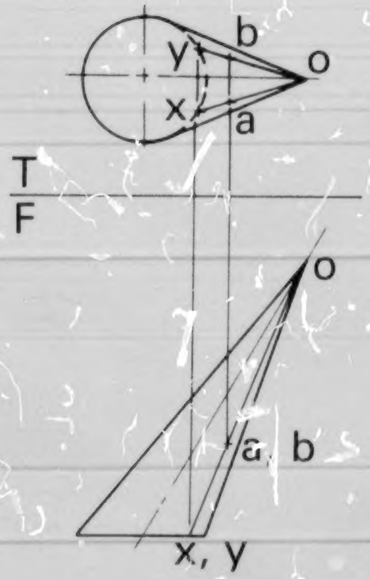
True Sizes By Rotation

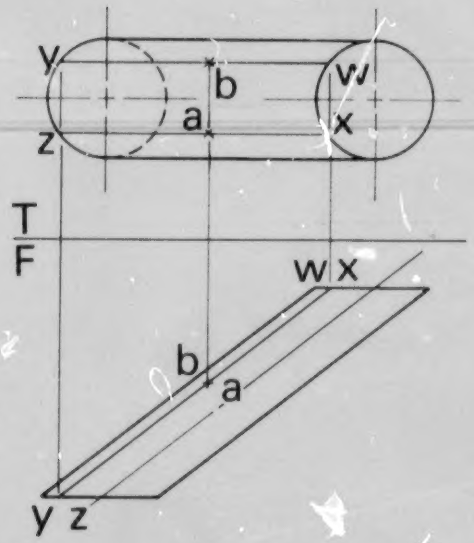

z r
F
y r
z
y
EV
F S
y r
y
TS
z r
S
z
Axis

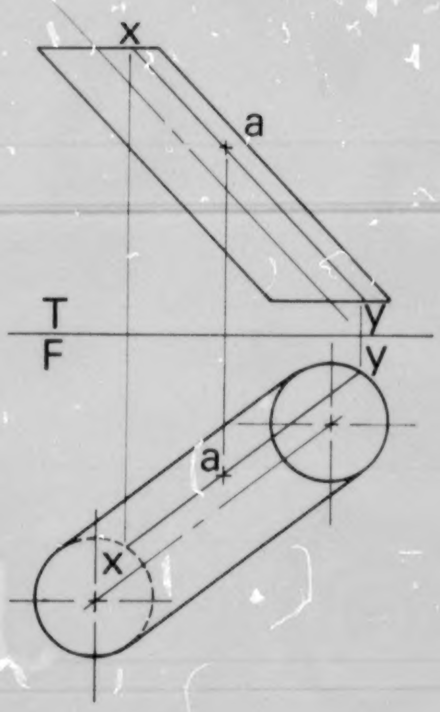

b
EV
a
b T
x
TL
a r
c 1
a
c
T 1
a r
TS
c r
c r
T
F
b F
a
x
c

Elements of Single Curved Surfaces

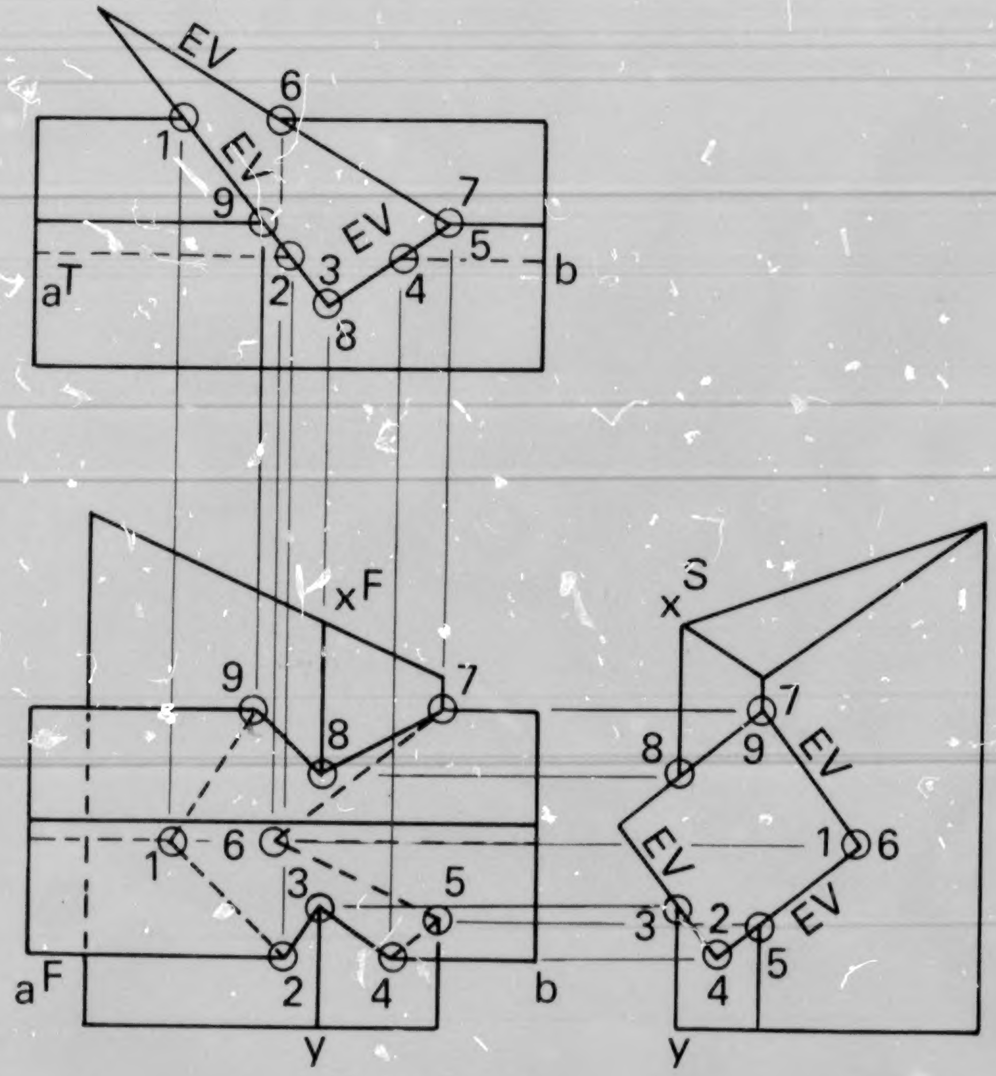



b
y
o
x
a
T
F
o
a, b
x, y

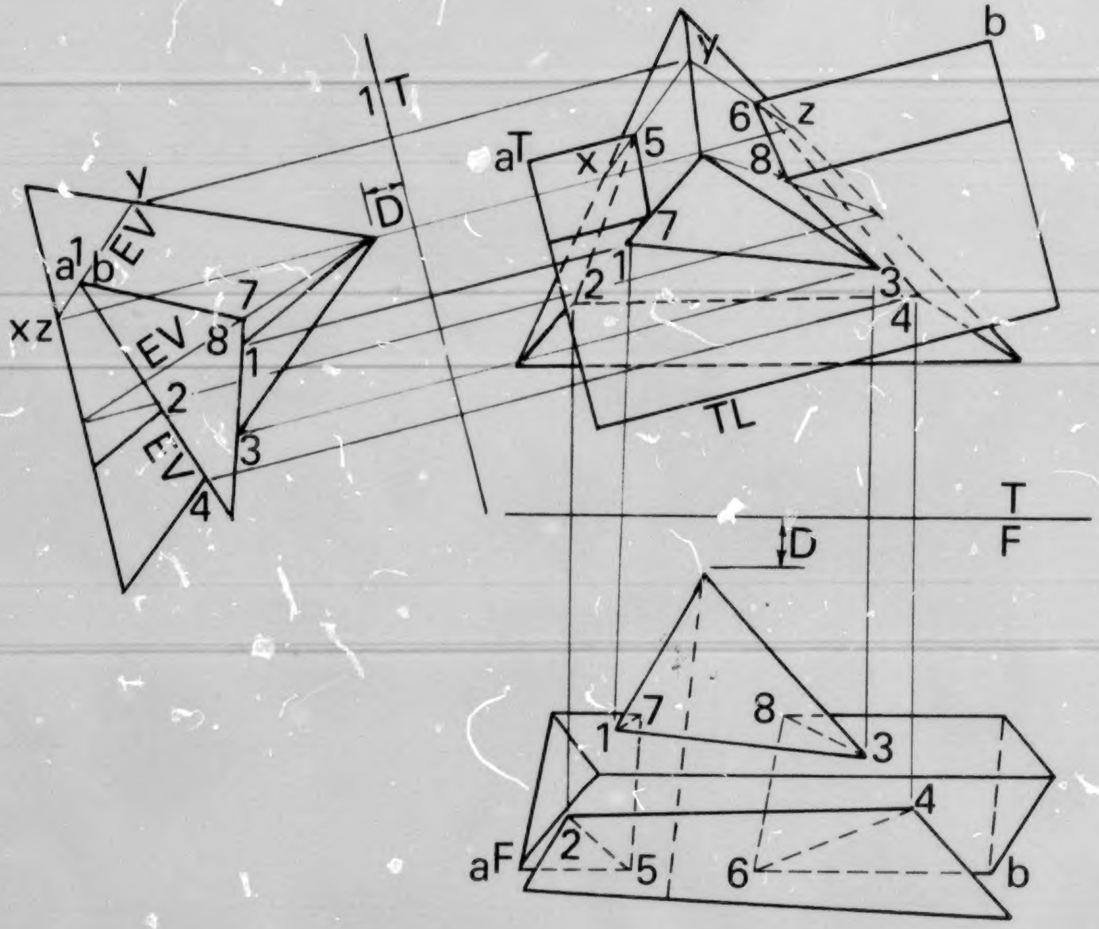

y
b
w
a
x
z
T
F
w x
b
a
y z



Intersections With Edge View Given

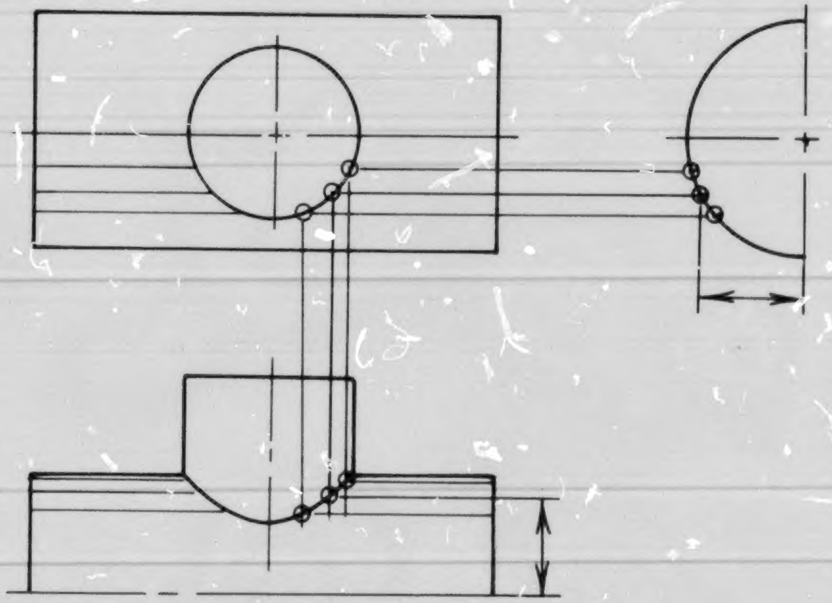

EV
6
1
EV
9
7
EV
5
aT
2
3
4
b
8
xF
9
7
8
1
6
3
5
aF
2
4
b
y
xS
7
8
9
EV
1
6
EV
3
2
EV
4
5
4
y

Intersections Using Auxiliary Views

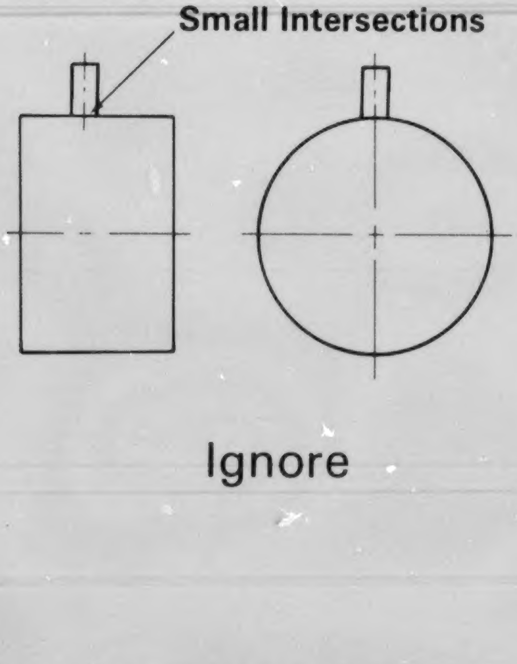


1 T
D
y
a1
b
EV
xz
7
8
EV
1
2
3
EV
4
y
b
6
z
aT
x
5
8
7
1
2
3
4
TL
T
F
D
7
8
1
3
4
2
aF
5
6
b

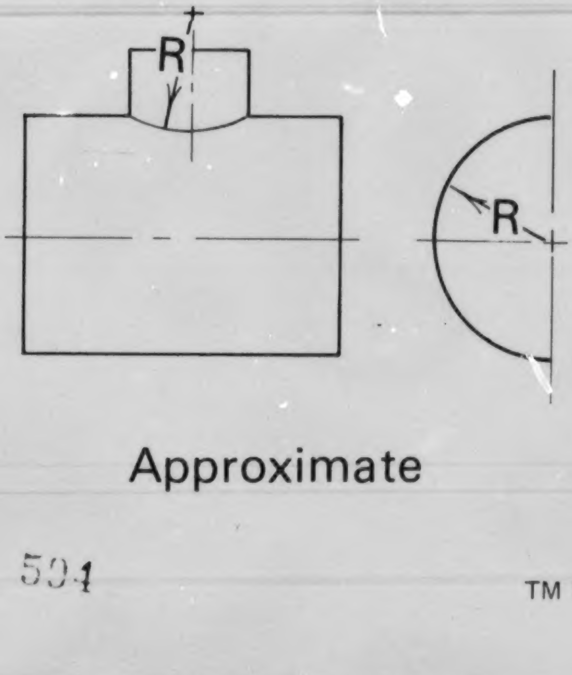
Intersections of Cylinders



Projection

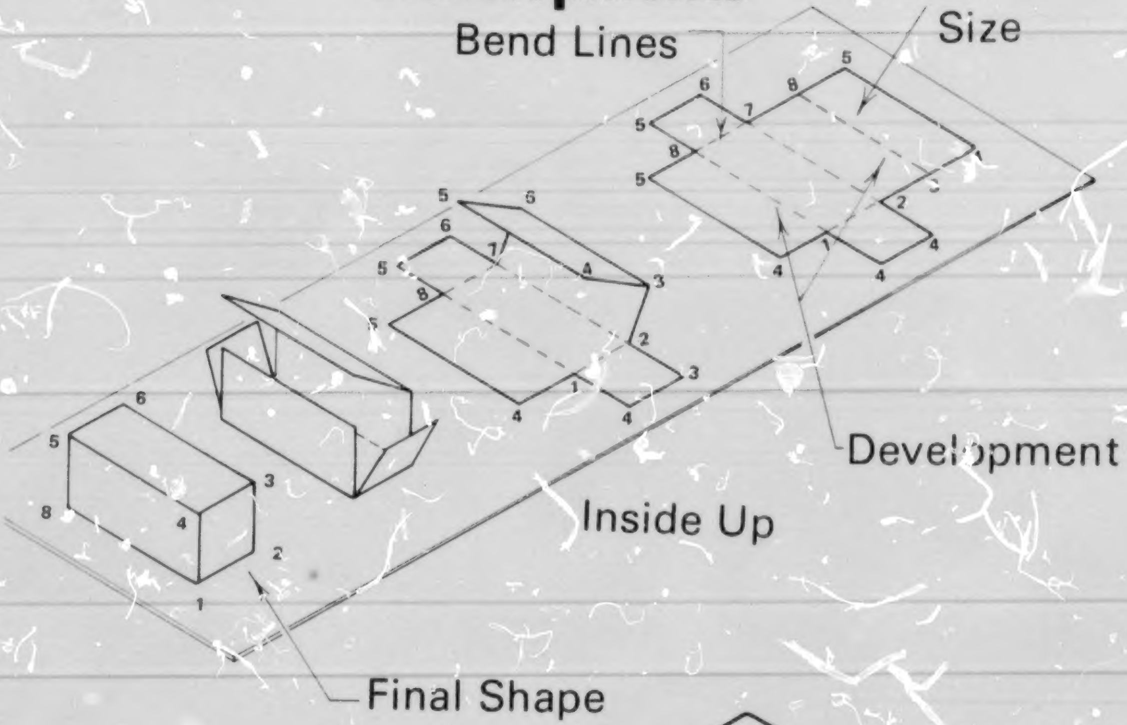

Small Intersections

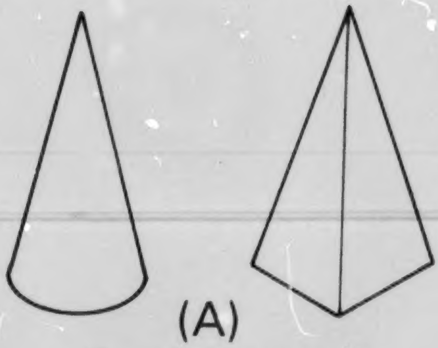
Ignore



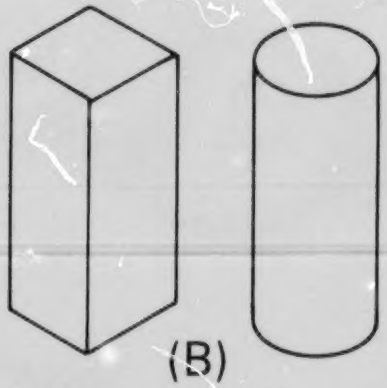
Approximate

Developments

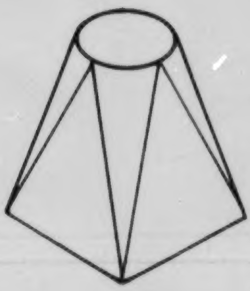

True Size
Bend Lines
5
6
8
7
5
8
5
5
6
6
5
7
4
3
5
8
5
2
3
1
4
4
2
1
4
4
4
Development
Inside Up
6
5
3
8
4
2
1
Final Shape



(A)
Radial Line

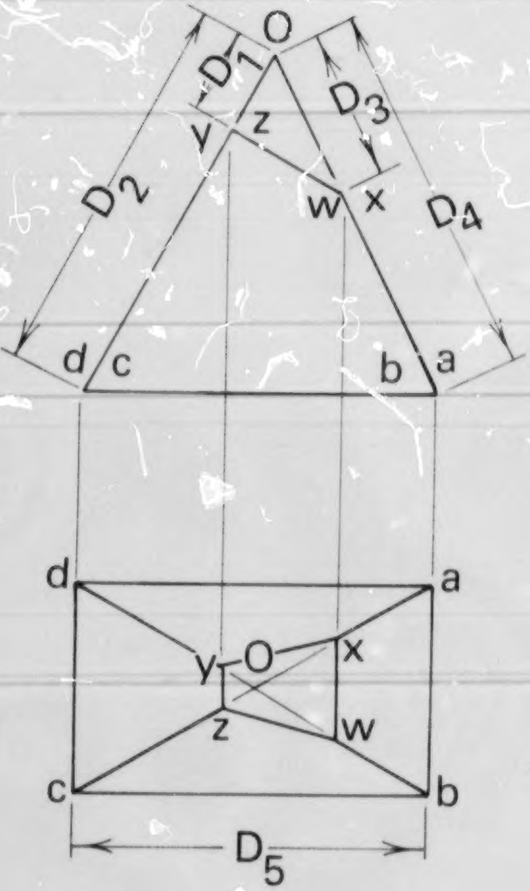


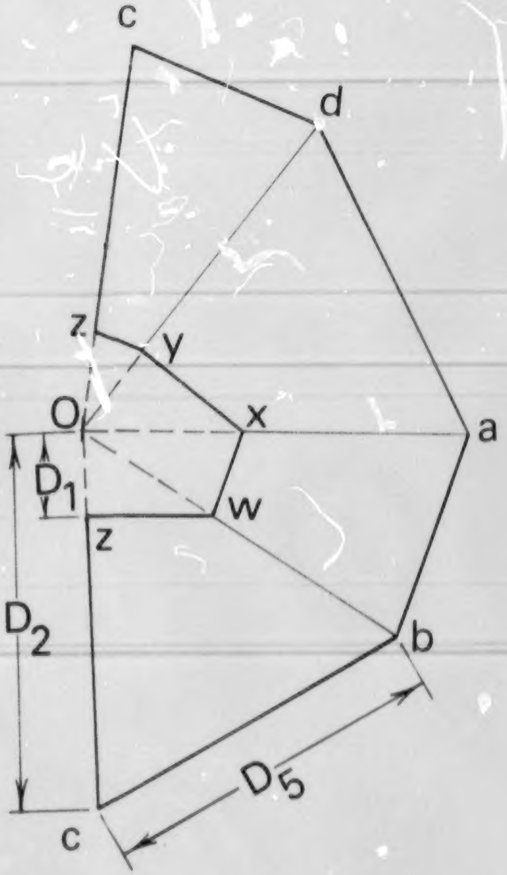
(B)
Parallel Line



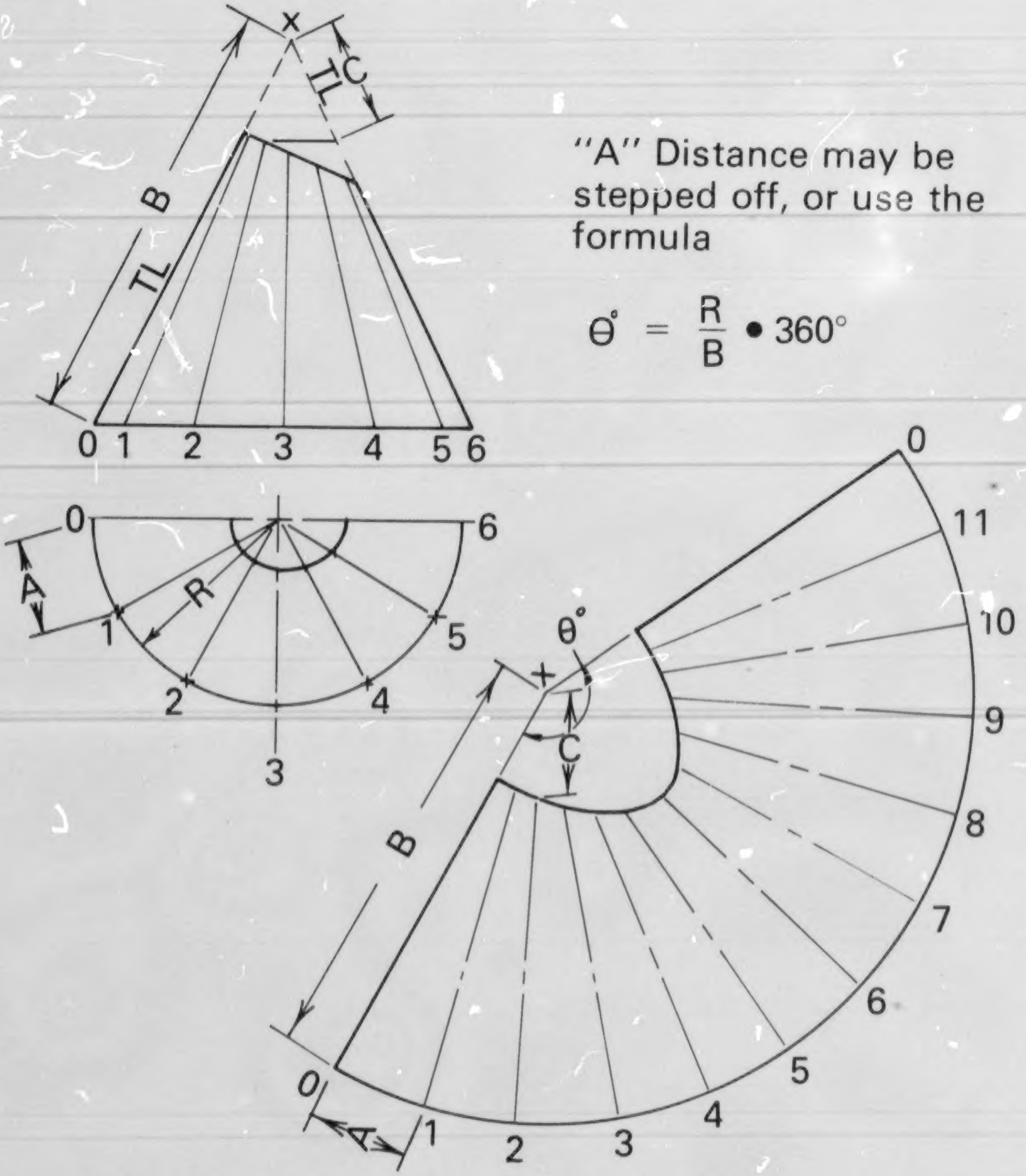
(C)
Triangulation

Radial Line Developments
Pyramids


O
D1
D3
D2
D4
y
z
w
x
d
c
b
a
d
a
y
O
x
z
w
c
b
D5


c
d
z
y
O
x
a
D1
w
z
D2
b
D5
c

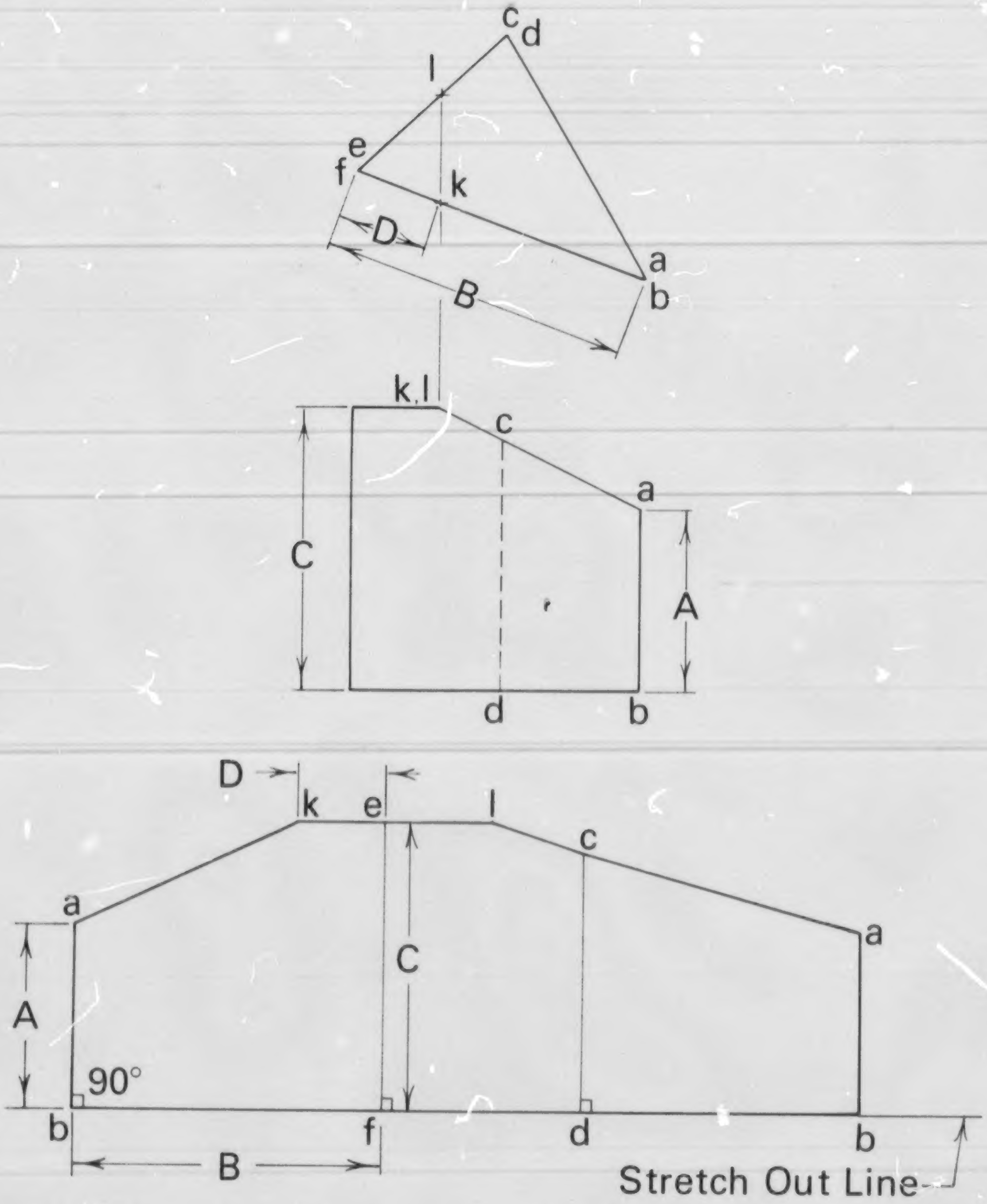
Radial Line Developments
Cones


x
C
TL
B
TL
0
1
2
3
4
5
6
0
6
A
R
1
2
3
4
5
θ°
x
C
B
0
11
10
9
8
7
6
5
4
3
2
1
0
A

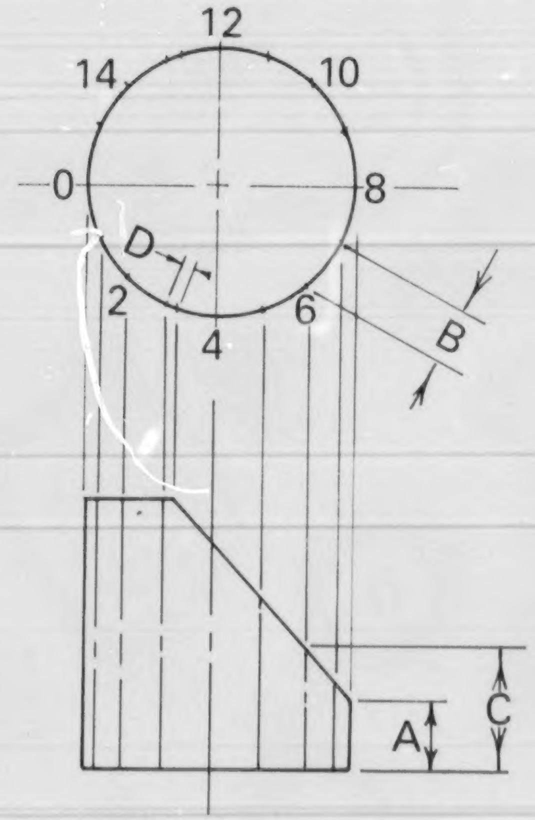
"A" Distance may be stepped off, or use the formula

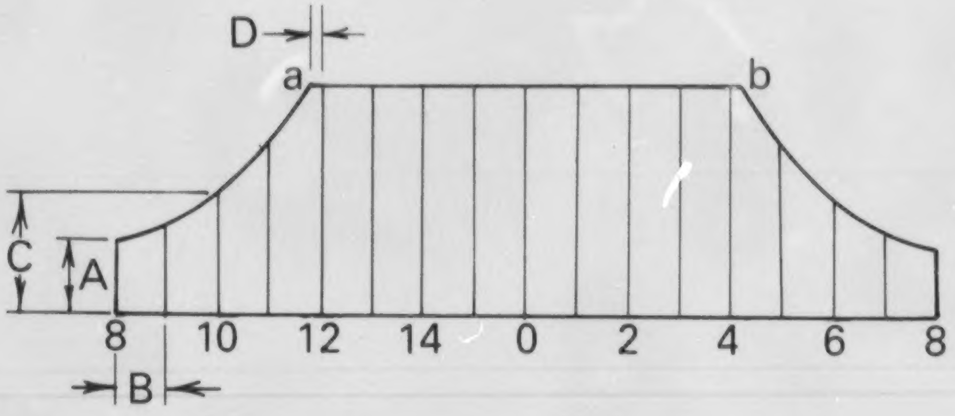
$$\theta^\circ = \frac{R}{B} \bullet 360^\circ$$

Parallel Line Developments
Prisms

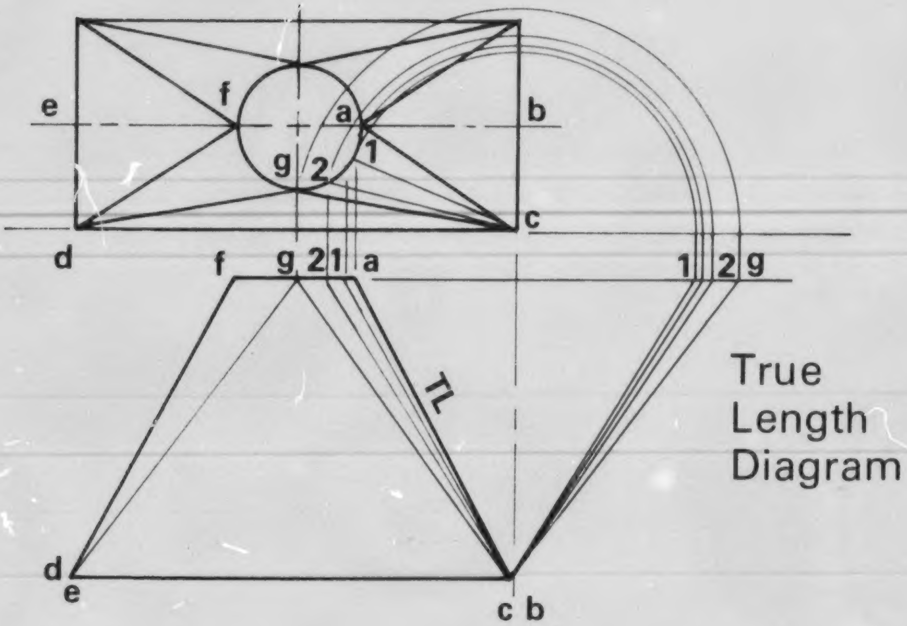

c
d
l
e
f
k
D
a
b
B
k,l
c
a
C
A
d
b
D
k
e
l
c
a
a
C
A
90°
b
f
d
b
B
Stretch Out Line

Parallel Line Developments
Cylinders

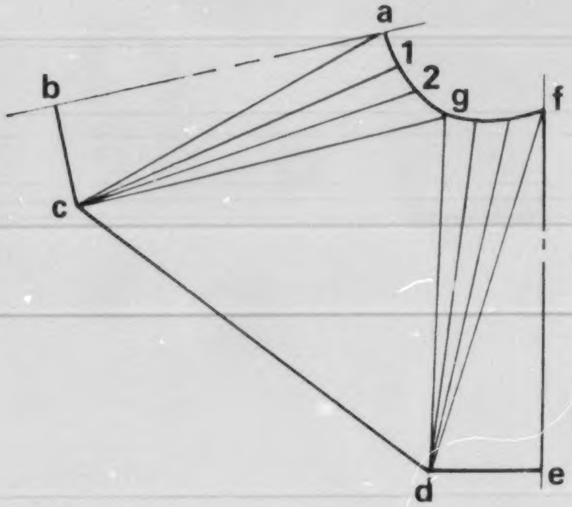

12
14
10
0
8
D
2
4
6
B
C
A


D
a
b
C
A
8
10
12
14
0
2
4
6
8
B

Triangulation


e
f
a
b
1
g
2
c
d
d
f
g
2
1
a
1
2
g
TL
True
Length
Diagram
d
e
c
b

Half Development



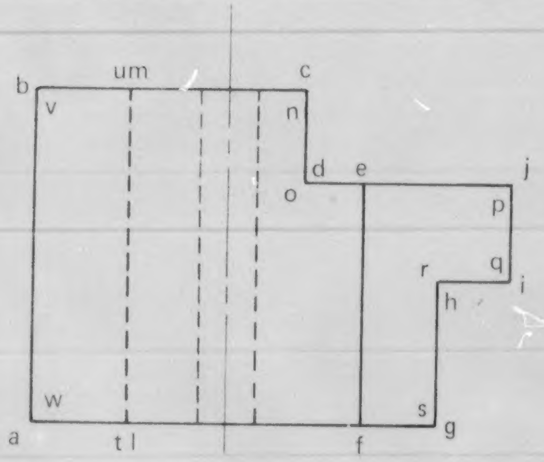
SHEET METAL DEVELOPMENTS
UNIT X

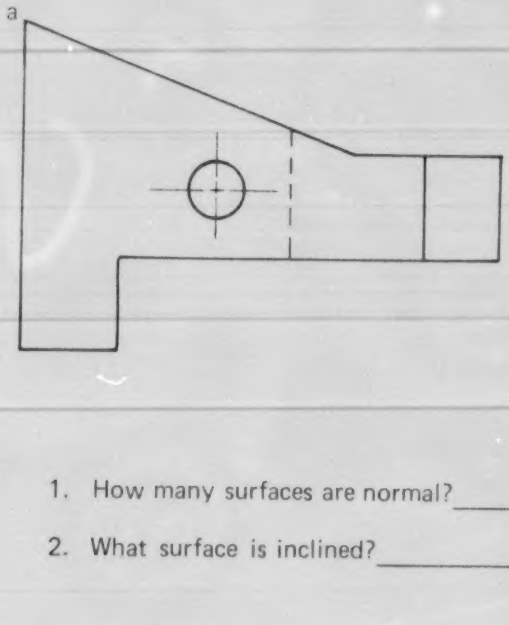
ASSIGNMENT SHEET #1--LABEL POINTS, LINES, AND PLANES IN VIEWS

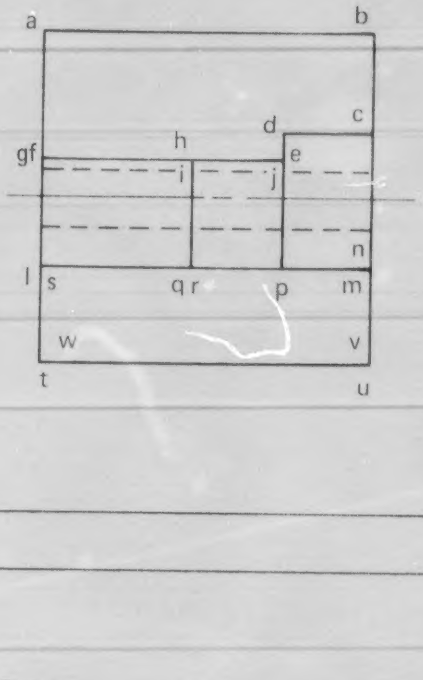
Directions: Using the drawings accompanying each problem, label all points on the view indicated, and answer the questions. Refer to Transparency 3 for examples.

Problems:

A. Label points on front view


b
um
c
v
n
d
e
j
o
p
r
q
i
h
w
s
a
t l
f
g



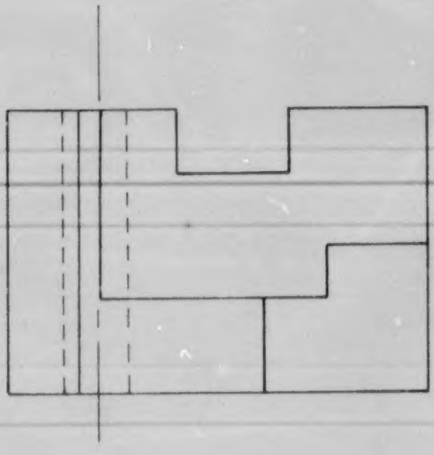

a
b
d
c
h
gf
e
i
j
n
l
s
q r
p
m
w
v
t
u

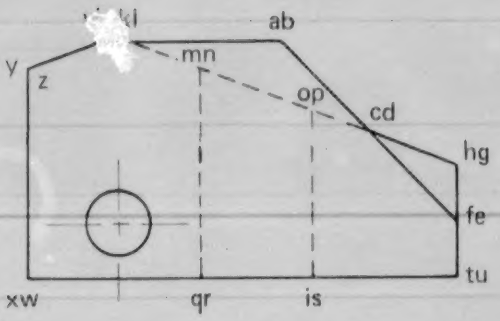
1. How many surfaces are normal?______________________________

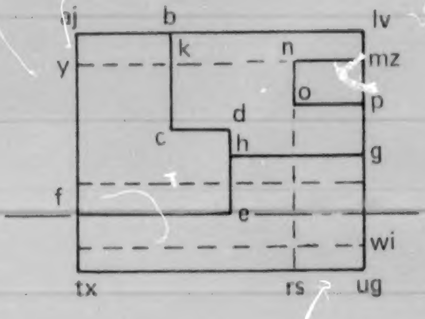
2. What surface is inclined?__________________________________

ASSIGNMENT SHEET #1

B. Label points on top view




kl
ab
y
z
mn
op
cd
hg
fe
tu
xw
qr
is


aj
b
lv
k
n
mz
y
o
p
d
c
h
g
f
e
wi
tx
rs
ug

1. What surfaces are inclined?____________________________________

2. Do you see the similar surfaces of the inclined surfaces?____________________

   (NOTE: If you don't, ask your instructor for assistance.)

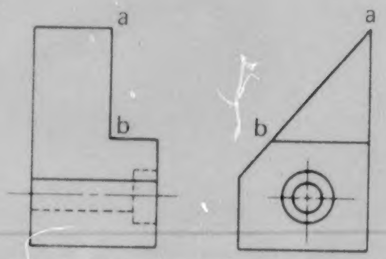
3. Is surface hgutfe normal, inclined, or oblique?__________________________

4. Is surface abcdef normal, inclined, or oblique?__________________________

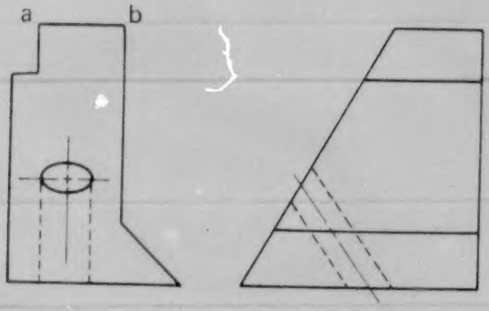
ASSIGNMENT SHEET #1

C. Label lines indicated

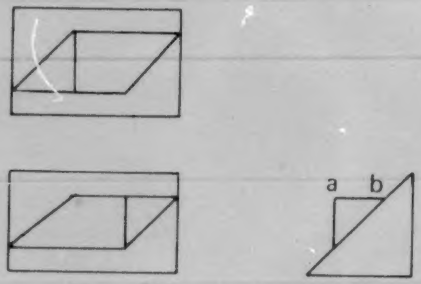
Example:



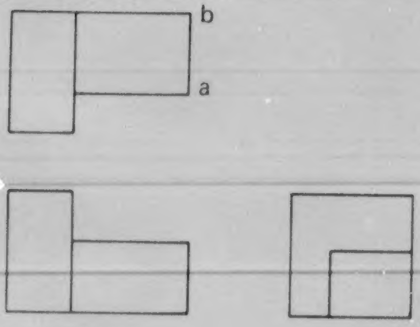
1.



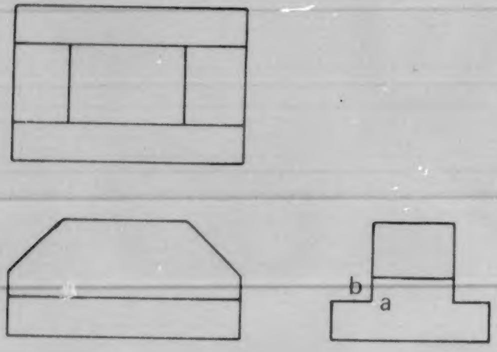
2.



3.

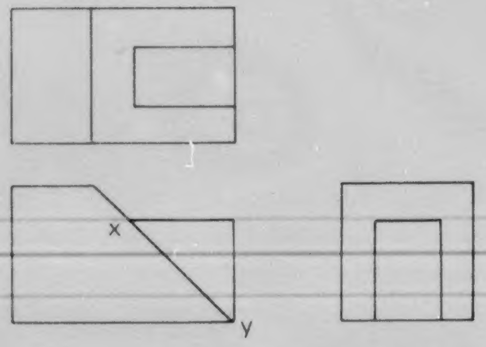


4.



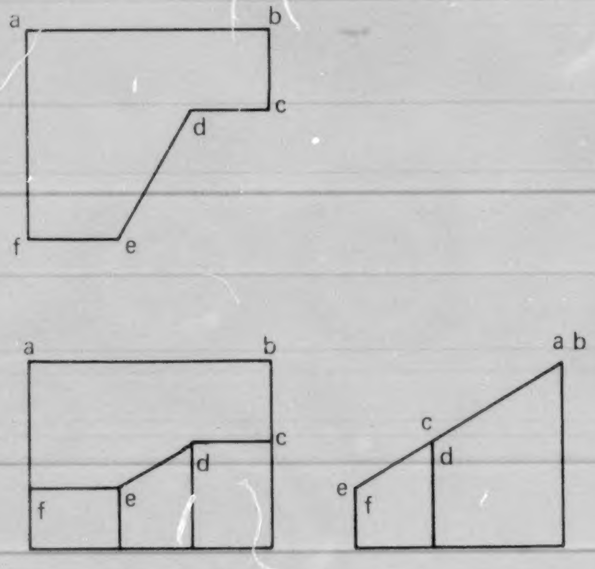
ASSIGNMENT SHEET #1

5.



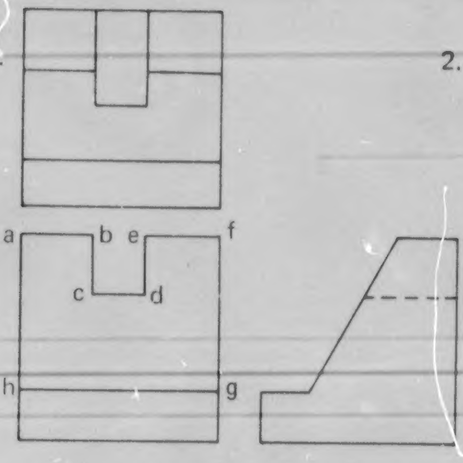
D. Label projected surfaces indicated

Example:

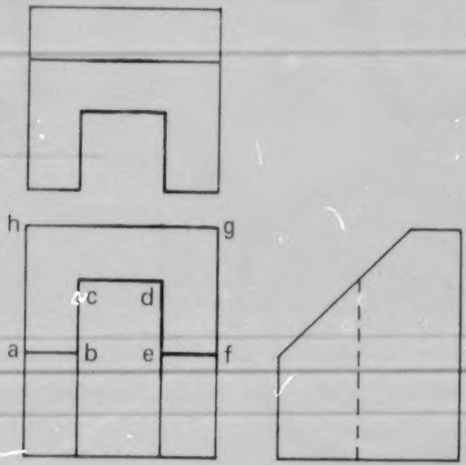

a
b
c
d
f
e
a
b
c
f
e
d
a b
c
d
e
f

ASSIGNMENT SHEET #1

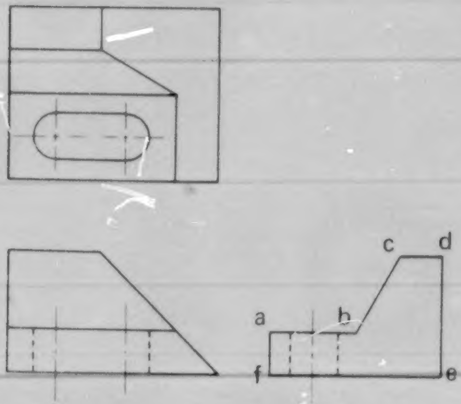
1.



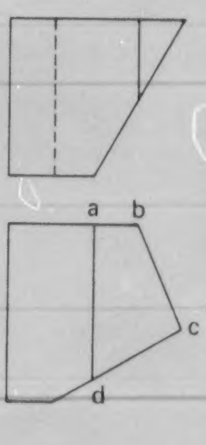
2.



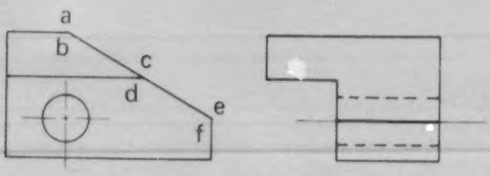
3.



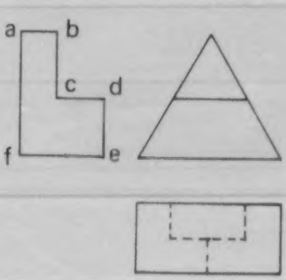
4.



5.

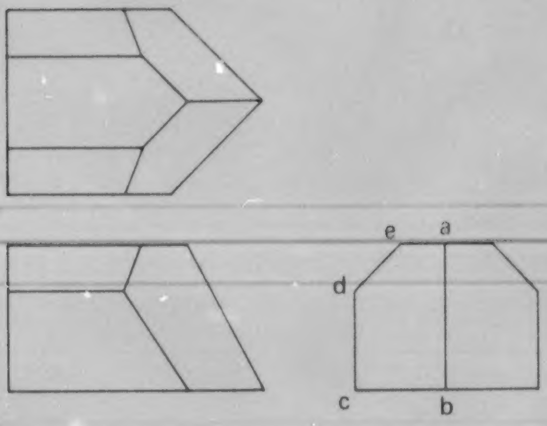


6.

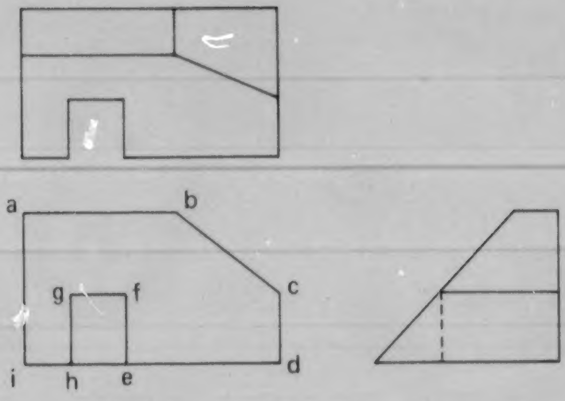


ASSIGNMENT SHEET #1

7.



8.



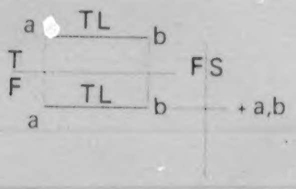
SHEET METAL DEVELOPMENTS
UNIT X

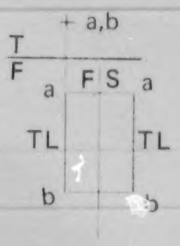
ASSIGNMENT SHEET #2--IDENTIFY TRUE LENGTHS AND TYPES OF LINES

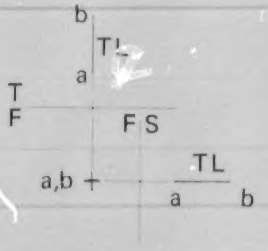
Directions: Identify true lengths and types of lines for the following problems. An example is included and is to be used as a review of the material covered in the information sheet and Transparencies 4 and 6.

Example:

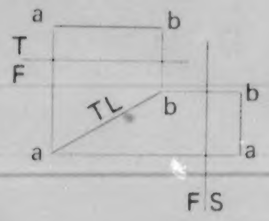
1. Normal line--Is in its true length in two views and a point view in a third view

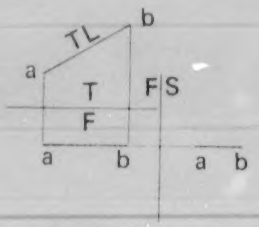

a
TL
b
T
F
F S
TL
b
+ a,b
a

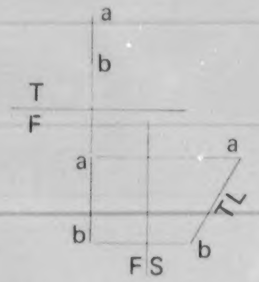

+ a,b
T
F
a
F S
a
TL
TL
b
b


b
TL
a
T
F
F S
TL
a,b +
a
b

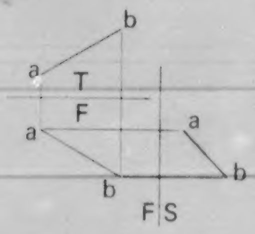
2. Inclined line--Is in true length in one view and not in true length in the other two views

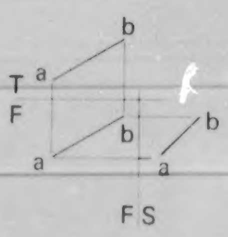

a
b
T
F
TL
b
b
a
a
F S

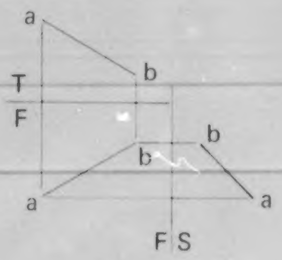

b
TL
a
T
F S
F
a
b
a
b


a
b
T
F
a
a
TL
b
b
F S

3. Oblique or skewed line--Is not in true length in any view


b
a
T
F
a
a
b
b
F S

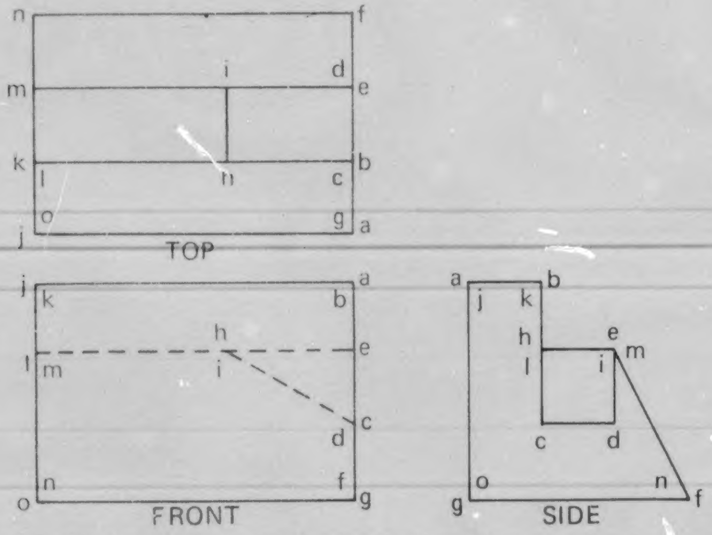

b
T
a
F
b
b
a
a
F S


a
b
T
F
b
b
a
a
F S

ASSIGNMENT SHEET #2

Problems: Complete the tables by identifying all true length lines and non-true length lines, and indicate if line is normal, inclined, or oblique.

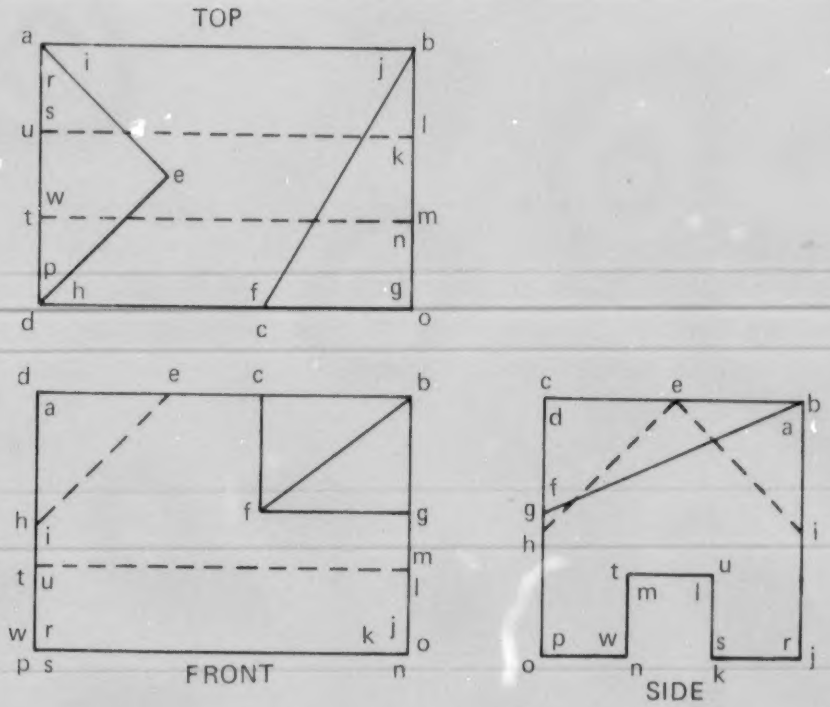
A.


n
f
i
d
m
e
k
b
l
h
c
o
g
j
a
TOP
j
a
k
b
h
l
e
m
i
c
d
n
f
o
g
FRONT
a
b
j
k
h
e
m
l
i
c
d
o
n
g
f
SIDE

LINE	VIEW TL IS LOCATED	NON-TL	TYPE OF LINE NORMAL	INCLINED	OBLIQUE
ab	Top & Side	--			
cd		--			
hc					
ef	Side				
nf	Top & Front	--			
oj		--	X		
gf	Top & Side	--			
hi		--			
id	Front	Top & Side			
eim		--			
lm		--			
og	Top & Front	--	X		

ASSIGNMENT SHEET #2

B.


TOP
a
b
i
j
r
s
u
l
k
e
w
t
m
n
p
h
f
g
d
c
o
d
e
c
b
a
h
i
f
g
m
t
u
l
w
r
k
j
o
p
s
FRONT
n
c
e
b
d
a
f
g
h
i
t
u
m
l
p
w
s
r
o
n
k
j
SIDE

			TYPE OF LINE		
LINE	VIEW TL IS LOCATED	NON-TL	NORMAL	INCLINED	OBLIQUE
cb					
go	Front & Side	--			
he	--				X
fg	Front & Side	--			
fb	--	Top, Front, & Side			
ab		--			
gb		Top & Front			
hi	Top & Side	--			
tu		--			

SHEET METAL DEVELOPMENTS
UNIT X

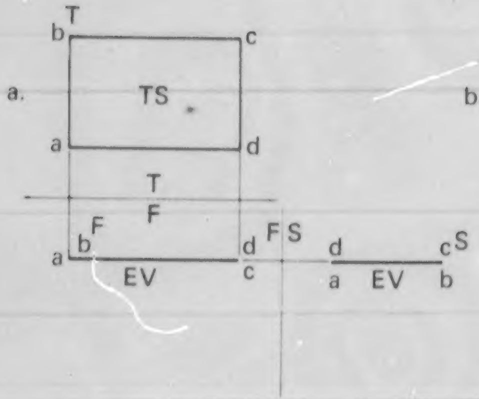
ASSIGNMENT SHEET #3--IDENTIFY TRUE SIZES AND TYPES OF PLANES

Directions: Identify true sizes and types of planes for the following problems. An example is included and is to be used as a review of the material covered in the information sheet and Transparencies 5 and 6.

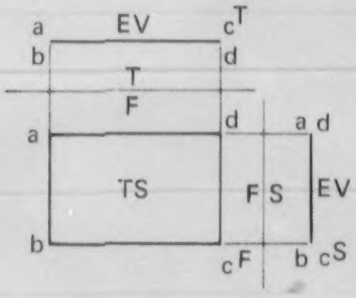
Example:

1. Normal plane--Is in true size in one view and in edge view in the other two views

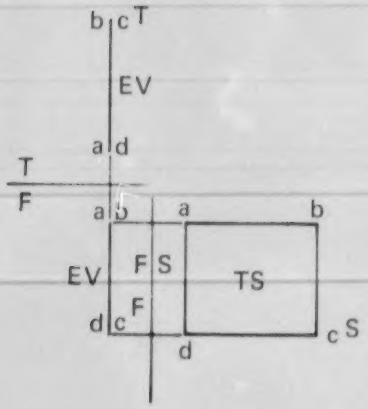
a.


T
b
c
TS
a
d
T
F
F
b
a
d
c
F S
d
c S
EV
a
EV
b

b.

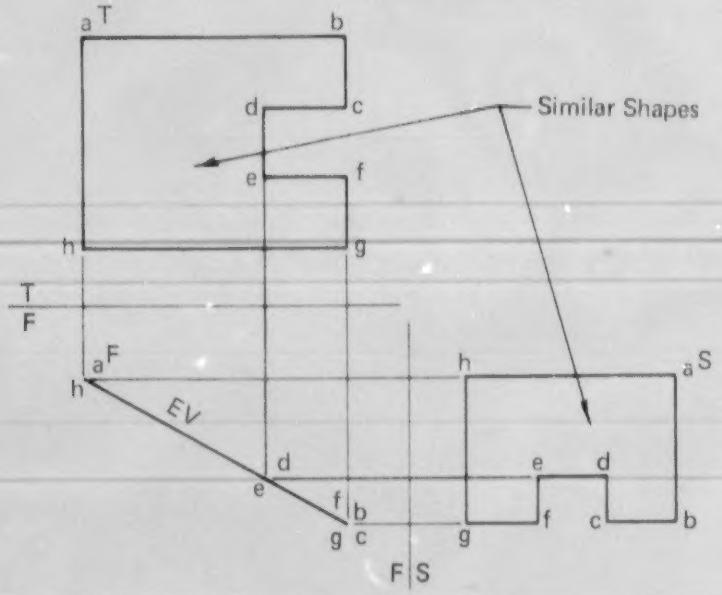

a
EV
c T
b
d
T
F
d
a d
a
TS
F S
EV
b
c F
b c S

c.


b c T
EV
a d
T
F
a b
a
b
EV
F S
TS
F
d c
c S
d

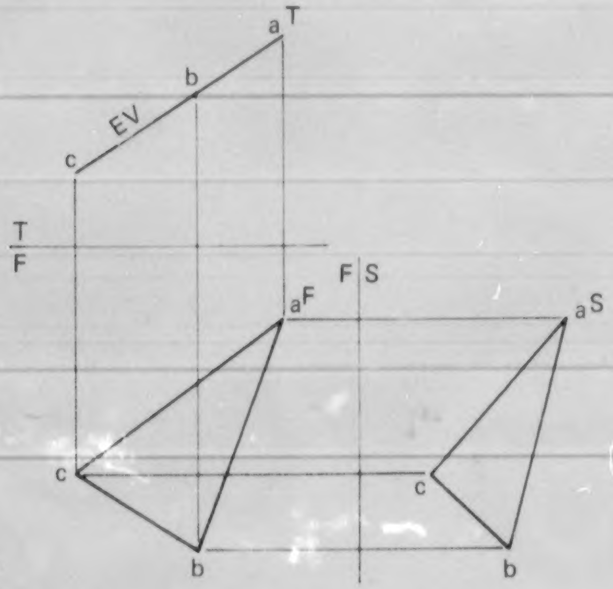
ASSIGNMENT SHEET #3

2. Inclined plane--Is not in true size in any regular view but can be observed as two similar surfaces in two views and as an edge in the other view


a T
b
d
c
Similar Shapes
e
f
h
g
T
F
a F
h
h
a S
EV
d
e
d
e
f
b
g
c
f
c
b
g
F S

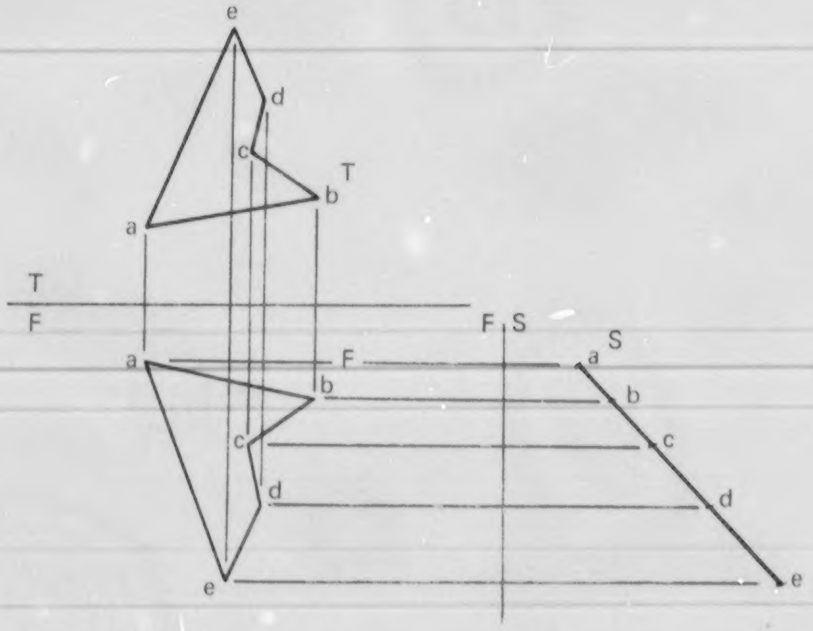
a.

(NOTE: Observe the similar surface with the same number of points and lines. The similar surfaces are not in true size.)


a T
b
EV
c
T
F
F S
a F
a S
c
c
b
b

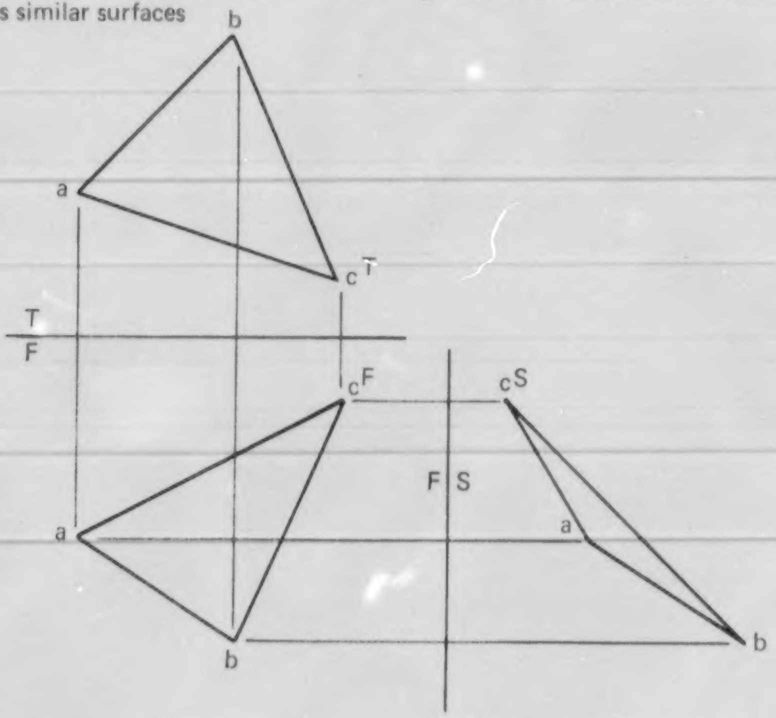
b.

ASSIGNMENT SHEET #3


e
d
c
b
T
a
T
F
F
S
a
F
a
S
b
b
c
c
d
d
e
e

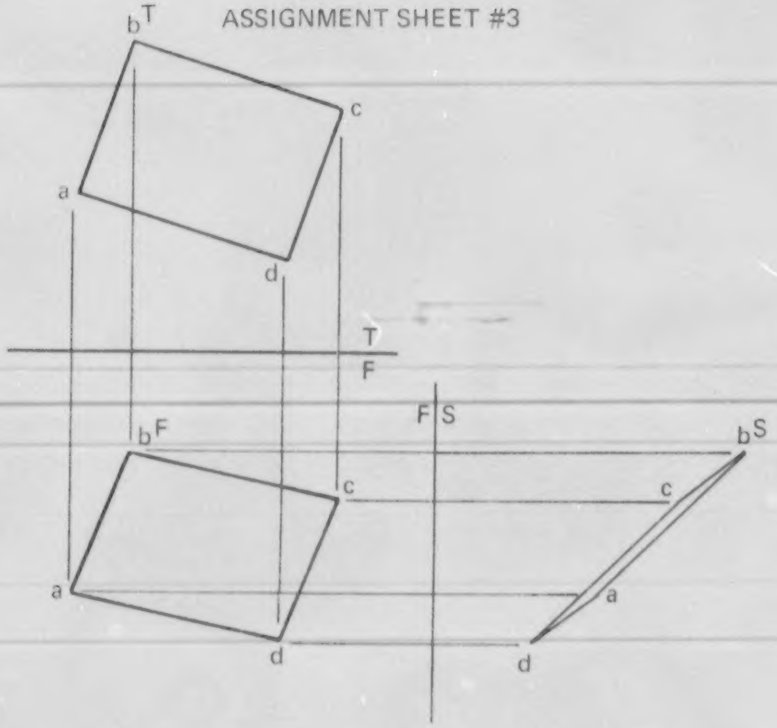
c.

3. Oblique plane--Is not in true size in any regular view; it can be observed in all three views as similar surfaces


b
a
c T
T
F
c F
c S
F S
a
a
b
b

a.

ASSIGNMENT SHEET #3


b^T
c
a
d
T
F
F|S
b^F
c
a
d
b^S
c
a
d

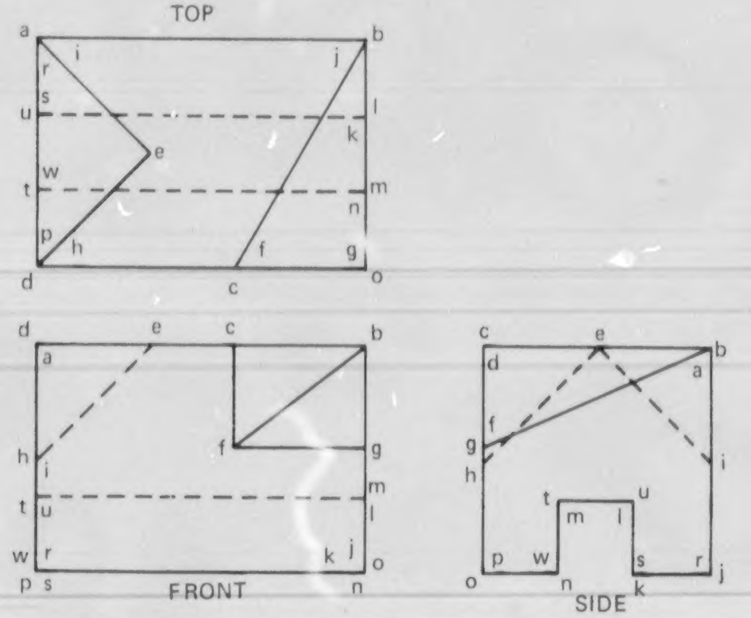
b.

(NOTE: Observe similar surfaces in all three views.)

ASSIGNMENT SHEET #3

Problems: Complete the tables by identifying all true size (TS) planes and non-true size planes, and indicate if plane is normal, inclined, or oblique.

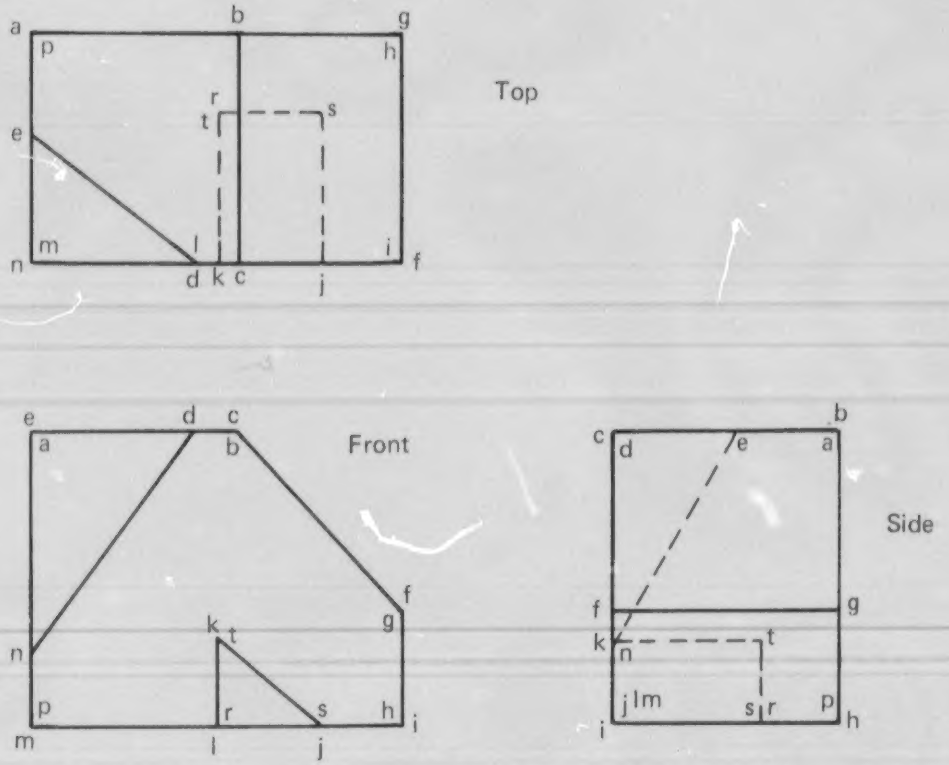
A.


TOP
a
b
i
j
r
s
u
l
k
e
w
t
m
n
p
h
f
g
d
c
o
d
e
c
b
a
h
i
f
g
t
u
m
l
w
r
k
j
o
p
s
n
FRONT
c
e
b
d
a
f
g
h
i
t
u
m
l
p
w
s
r
o
n
k
j
SIDE

PLANE	VIEW TS IS LOCATED	VIEW NON-TS IS LOCATED	VIEW EDGE VIEW IS LOCATED	TYPE OF PLANE		
				NORMAL	INCLINED	OBLIQUE
cbf	--		Top			
abcde	Top	--	Front & Side			
deh	--				X	
tmlu	Top	--	Top & Side			
bfg	--	Top & Front				

ASSIGNMENT SHEET #3

B.


a
b
g
p
h
Top
r
s
t
e
m
l
i
n
d
k
c
j
f
e
d
c
a
b
Front
f
g
k
t
n
p
r
s
h
i
m
l
j
c
d
e
b
a
Side
f
g
k
n
t
j
l
m
s
r
p
i
h

PLANE	VIEW TS IS LOCATED	VIEW NON-TS IS LOCATED	VIEW EDGE VIEW IS LOCATED	TYPE OF PLANE NORMAL	INCLINED	OBLIQUE
abcde		--	Front & Side			
bgfc	--	Top & Side	Front			
rst		--		X		
mpni	Top	--	Front & Side			
end	--		--			

SHEET METAL DEVELOPMENTS
UNIT X

ASSIGNMENT SHEET #4--CONSTRUCT TRUE LENGTHS OF LINES AND TRUE SIZES OF PLANES USING AUXILIARY VIEWS

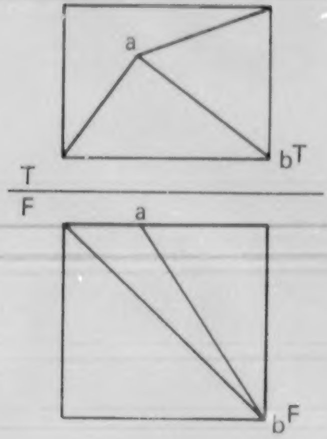
Directions: When a line is oblique to any principal view, an auxiliary view is required to find the true length. When a plane is inclined or oblique to any principal view, an auxiliary view is required to find the true size. Construct true lengths of lines and true sizes of planes and label the points.

(NOTE: Refer to "Auxiliary Views", Unit VI of *Basic Drafting, Book Two* for specific examples.)

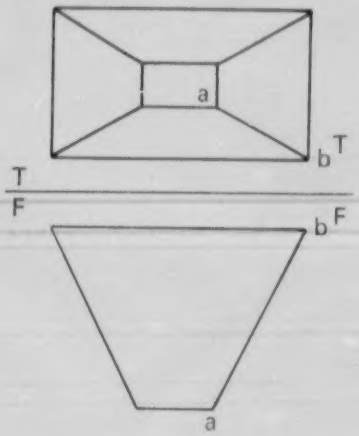
Problems:

A. Construct true lengths of the lines marked AB below using auxiliary view method. Label the points, and label the true length lines with TL.

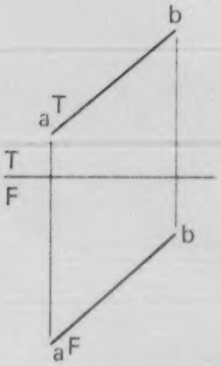
1.



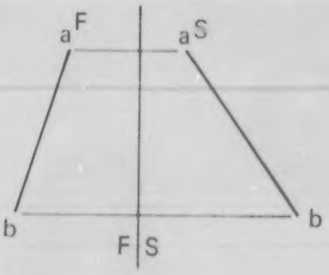
2. (Sheet metal)



3.



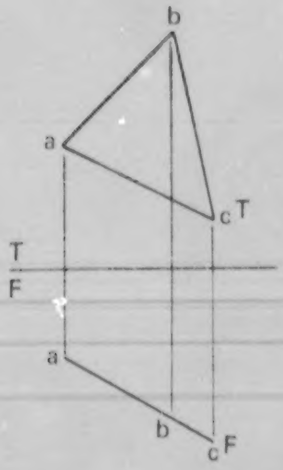
4.



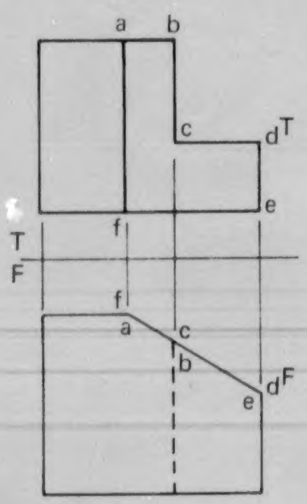
ASSIGNMENT SHEET #4

B. Construct true sizes of planes marked below using auxiliary views. Label the points, and label the true size with TS.

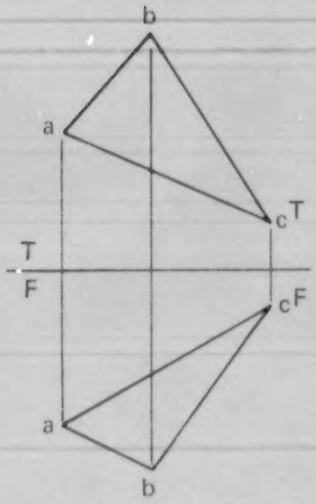
1.


b
a
c T
T
F
a
b
c F

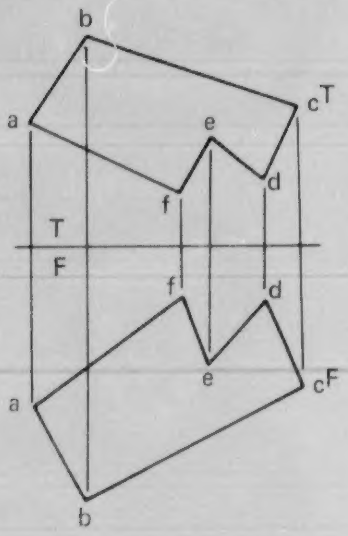
2.


a
b
c
d T
e
f
T
F
f
a
c
b
d F
e

3.


b
a
c T
T
F
c F
a
b

4.


b
c T
a
e
d
f
T
F
f
d
e
c F
a
b

SHEET METAL DEVELOPMENTS
UNIT X

ASSIGNMENT SHEET #5--CONSTRUCT TRUE LENGTHS OF LINES BY ROTATION

Introduction: In your previous study of orthographic projection and auxiliary views, the related principal views of an object are found by changing the position of the observer. This is the same as saying change the position of the line of sight. Different views of an object can also be obtained by rotating the object while the observer (LOS) stays stationary. This is the same as a fixed viewing direction (see Transparency 12). Rotation eliminates some of the auxiliary views previously needed. Rotation also adds the problem of confusion from overlapping views. This confusion can be reduced by using different colored pencils, by using overlays, or as in the case of developments, by using true length diagrams.

Directions: Construct true lengths of lines by rotation as outlined in the procedure of the following example.

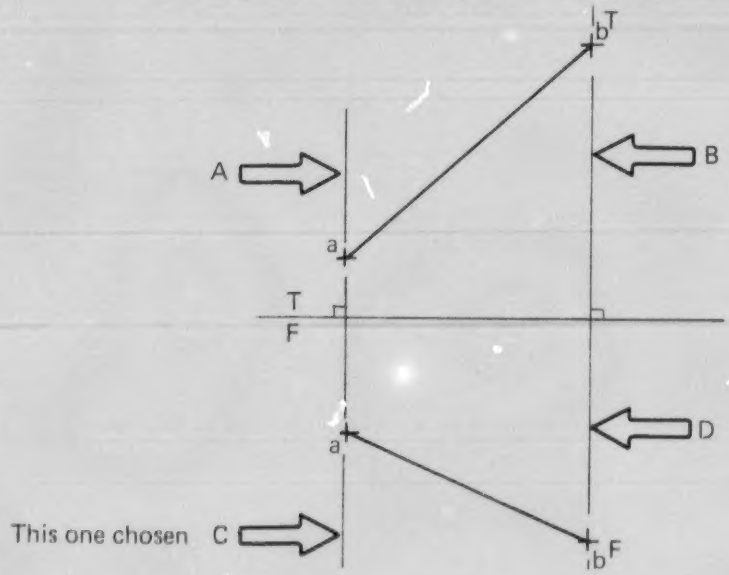
Example:

1. Select axis of rotation

   a. Any one of the following could be chosen: A, B, C, or D; it must be perpendicular to the folding line

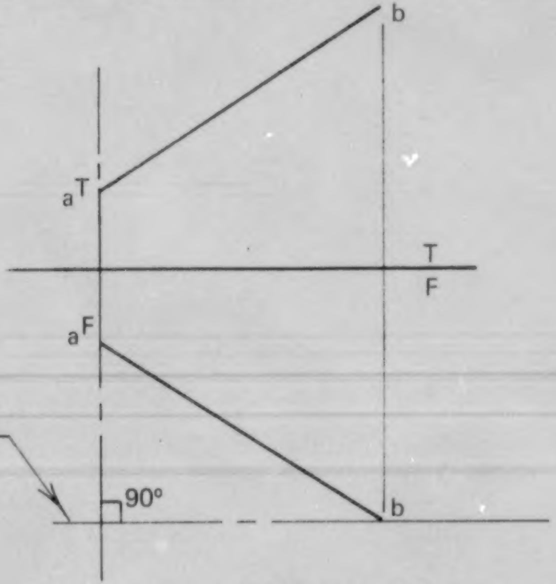
   b. Your choice depends on what view you want TL in and what point you want rotated

   c. In this example, axis "C" was chosen so TL will be in front view

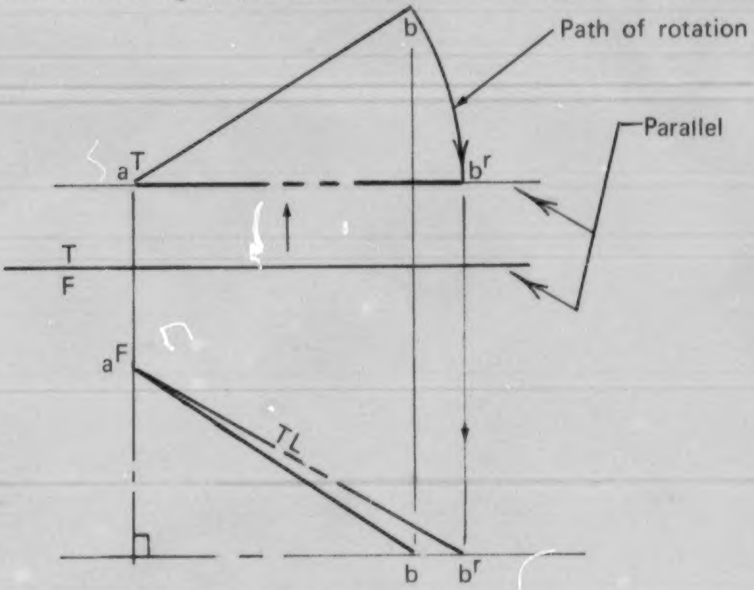


ASSIGNMENT SHEET #5

2. Construct path of rotation perpendicular to axis through the point to be rotated


b
a^T
T
F
a^F
Edge of
Path of rotation
90°
b

3. In the adjacent view, construct a path of rotation from "b" to a position where "ab" will be parallel to the folding line; mark new point b^r and project to adjacent view


b
Path of rotation
Parallel
a^T
b^r
T
F
a^F
TL
b
b^r

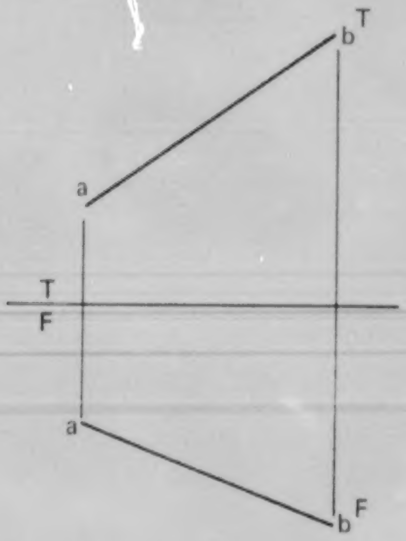
4. Connect "a" to the new b^r in the front view; mark it TL

(NOTE: Line ab^r is in TL because it has been rotated parallel to the front plane or perpendicular to the LOS.)

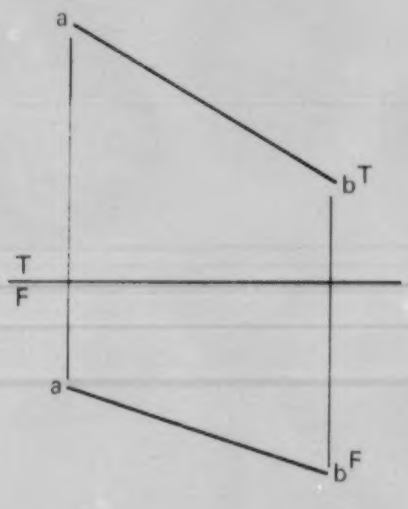
ASSIGNMENT SHEET #5

Problems:

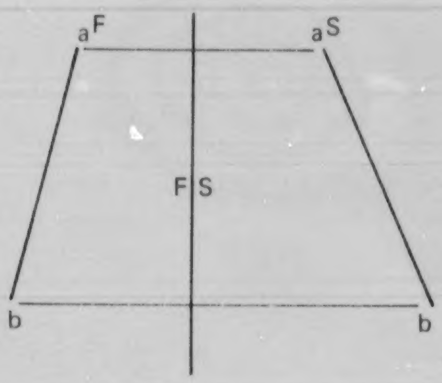
A. Find TL in front view



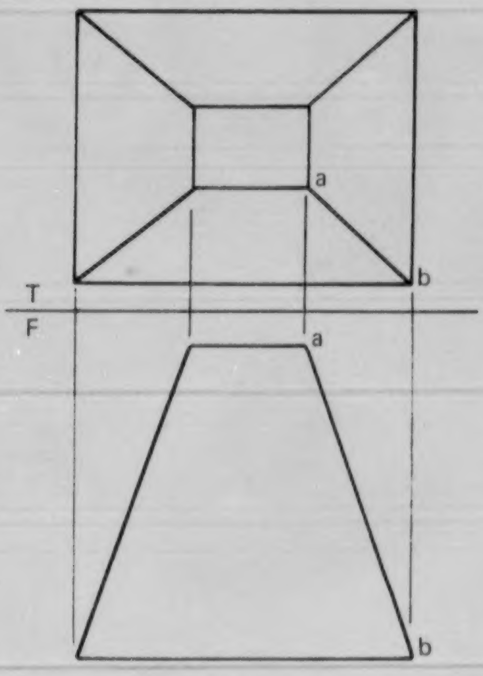
B. Find TL in top view



C. Find TL in side view

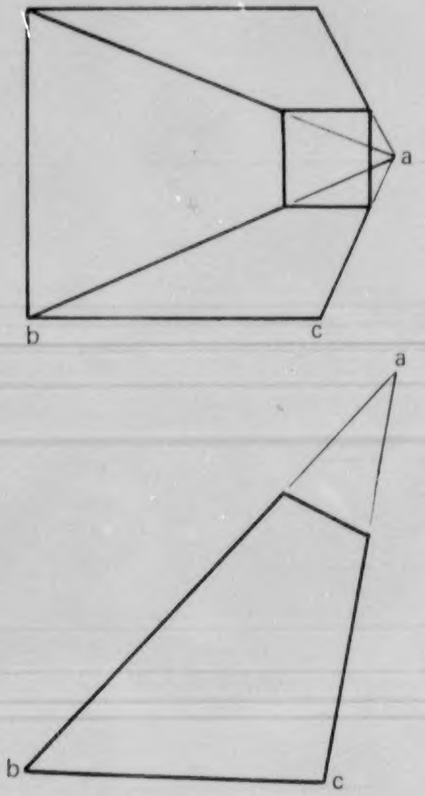


D. Find TL in front view



ASSIGNMENT SHEET #5

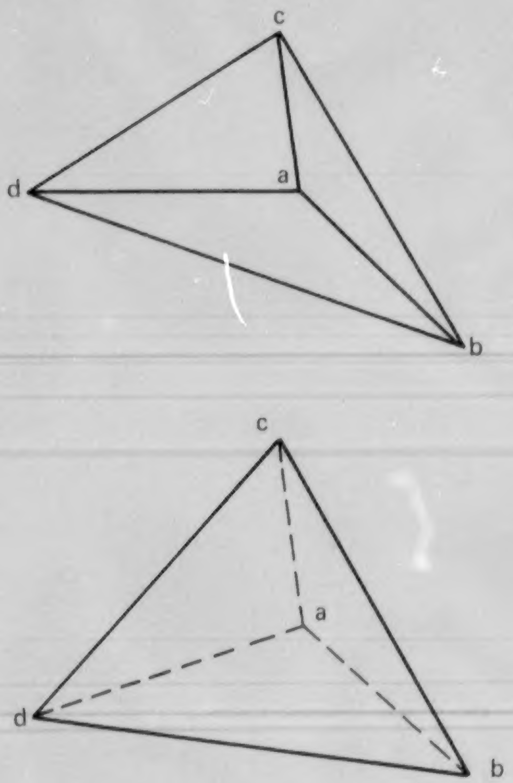
E. Find TL of ab and ac



TL of ab = ______________________

TL of ac = ______________________

F. Find TL of ab, ac, and ad



TL of ab = ______________________

TL of ac = ______________________

TL of ad = ______________________

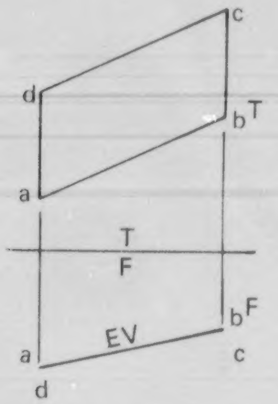
SHEET METAL DEVELOPMENTS
UNIT X

ASSIGNMENT SHEET #6--CONSTRUCT TRUE SIZES OF PLANES BY ROTATION

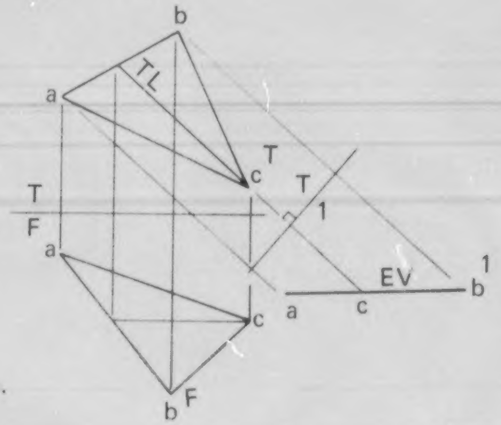
Directions: Construct true sizes of planes by rotation using the procedure in the following example as a guideline.

Example:

1. Construct or identify edge view of plane as shown in a and b


c
d
b
T
a
T
F
b
F
EV
a
c
d

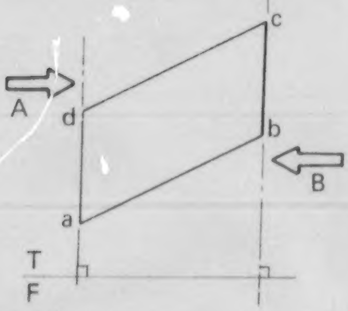
a.

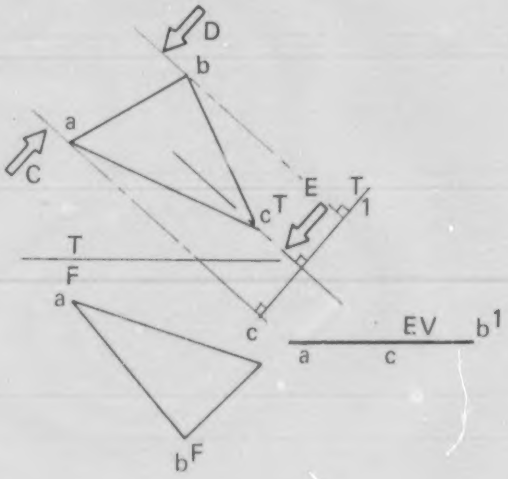

b
TL
a
c
T
T
1
T
F
a
c
EV
b
1
a
c
b
F

b.

2. Select axis of rotation

   a. Any axis could be chosen, but it must be perpendicular to the folding line next to the edge view

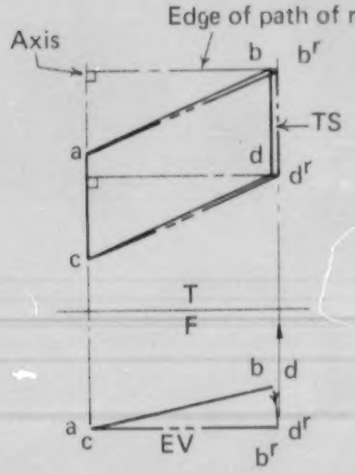



D
b
a
C
E
T
1
c
T
T
F
a
c
EV
b
1
a
c
b
F

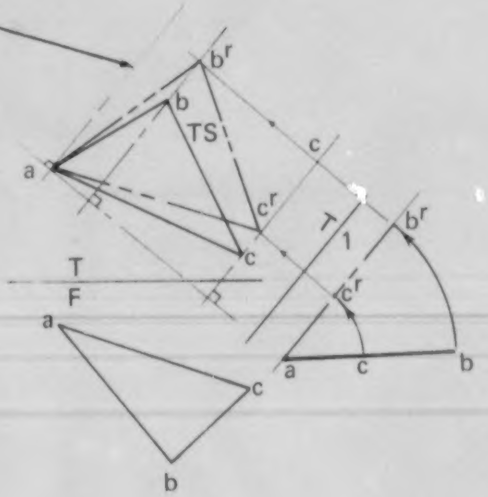
   b. Your choice depends on what points you want to rotate

ASSIGNMENT SHEET #6

3. Construct the edge of the path of rotation perpendicular to axis through the points to be rotated


Edge of path of rotation
Axis
b
b^r
TS
a
d
d^r
c
T
F
b
d
a
c
EV
b^r
d^r

a.


b^r
b
TS
a
c
c^r
c
T
1
b^r
c^r
T
F
a
a
c
b
c
b

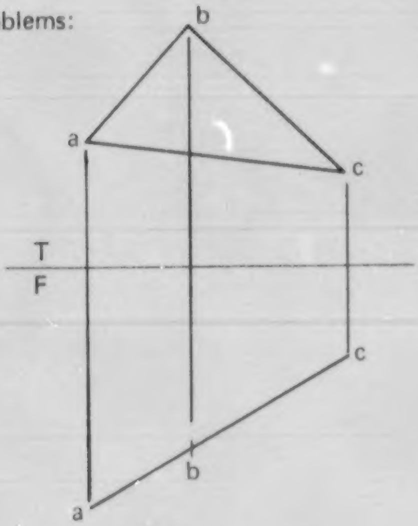
b.

4. In the edge view, construct a path of rotation from center point to a position parallel to folding line, and mark new point

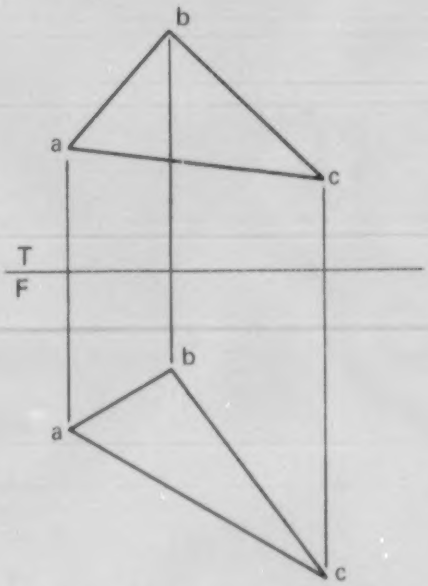
5. Connect all points forming true size of plane

Problems:

A.

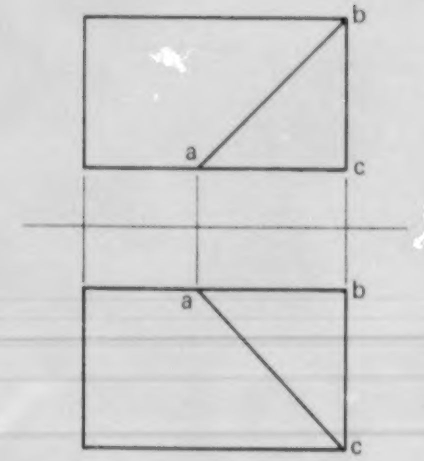


B.

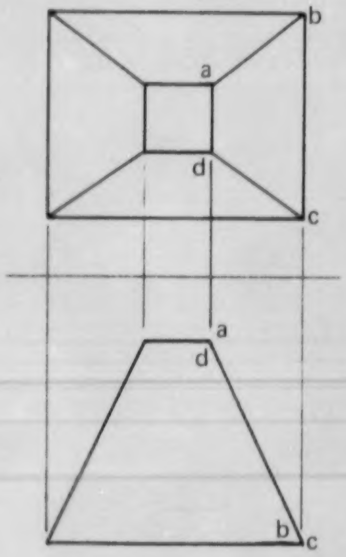


ASSIGNMENT SHEET #6

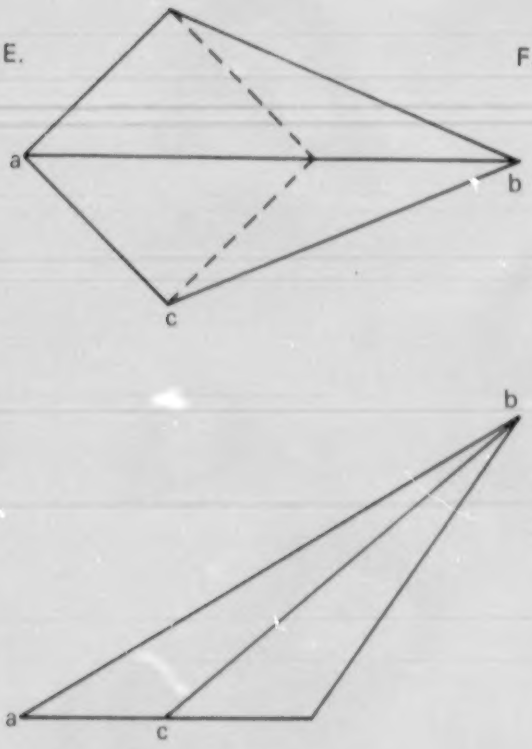
C.



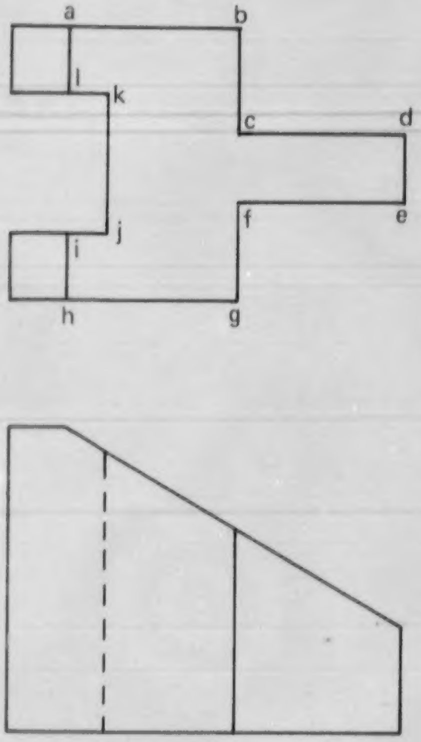
D.



E.

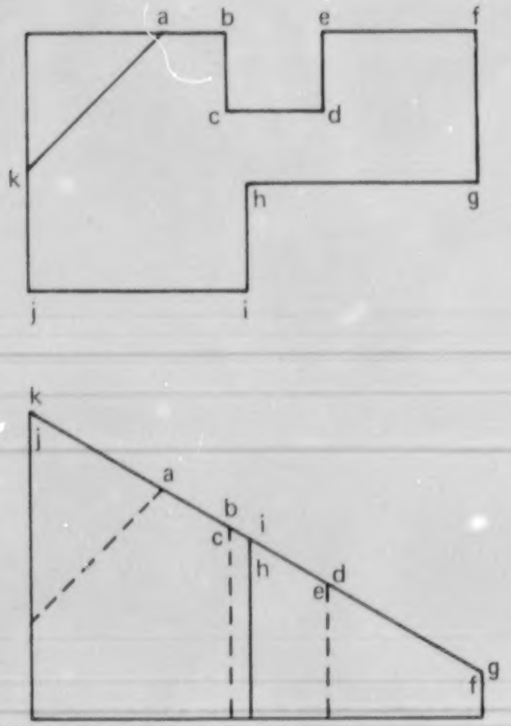


F.

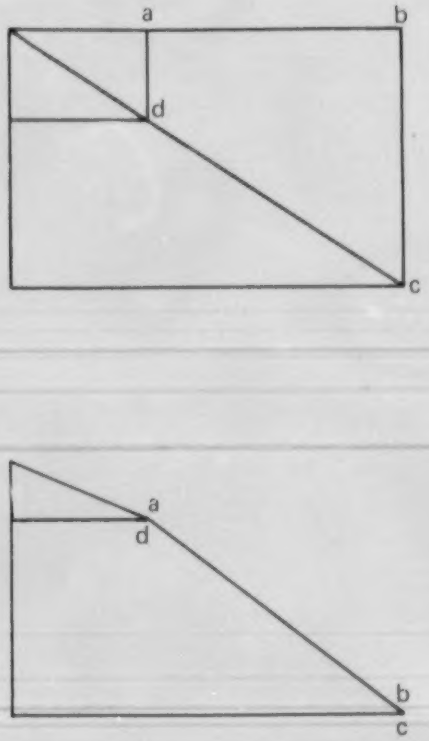

a
b
l
k
c
d
f
e
j
i
h
g

ASSIGNMENT SHEET #6

G.


a
b
e
f
c
d
k
h
g
j
i
k
j
a
b
c
i
h
d
e
g
f

H.



SHEET METAL DEVELOPMENTS
UNIT X

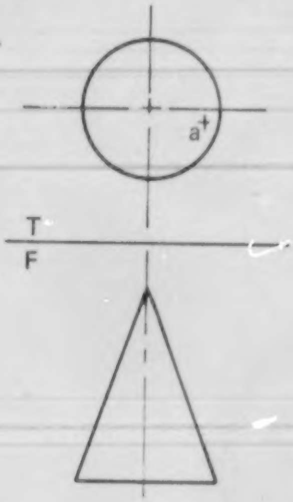
ASSIGNMENT SHEET #7--LOCATE ELEMENTS OF SINGLE CURVED SURFACES

Directions: Locate elements on the surfaces of the following single curved surfaces to locate point "a" in both views.

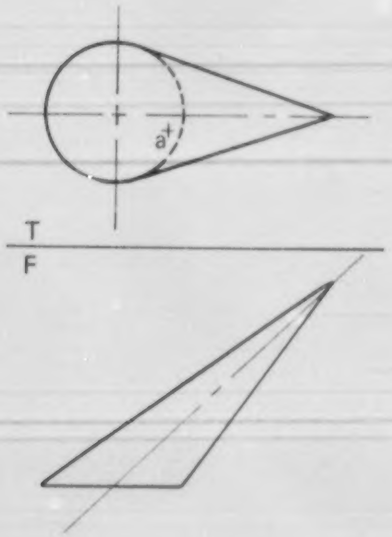
Problems:

A. Cones

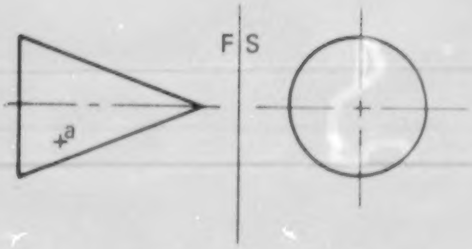
1.



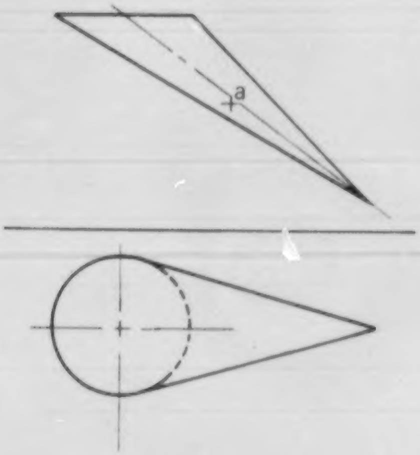
2.



3.



4.



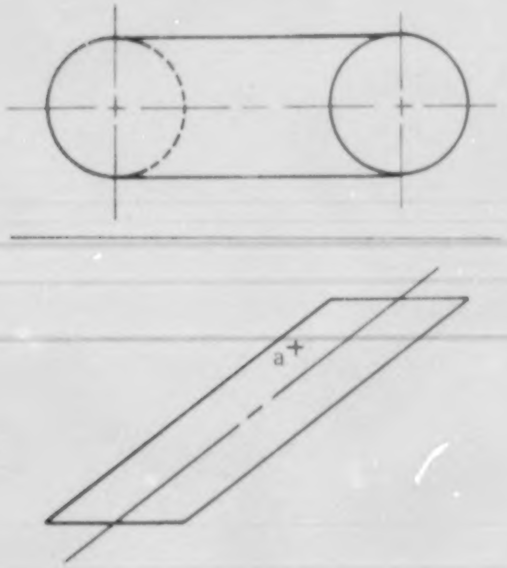
(NOTE: Two answers are possible for problems 3 and 4.)

ASSIGNMENT SHEET #7

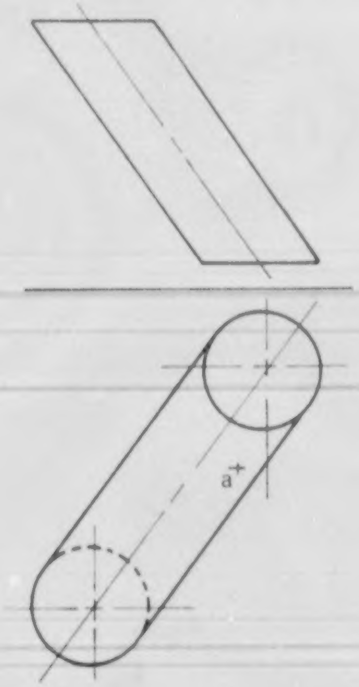
B. Cylinders

(NOTE: Two solutions are possible for these problems.)

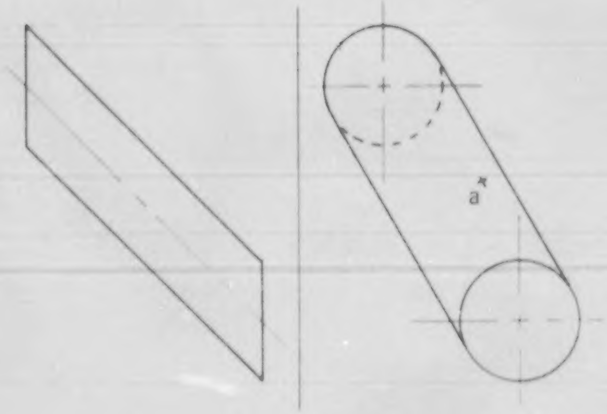
1.



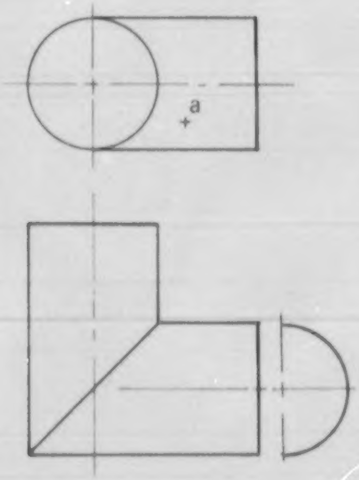
2.



3.



4.



SHEET METAL DEVELOPMENTS
UNIT X

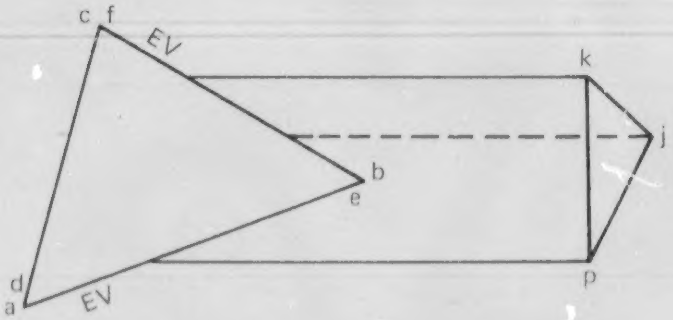
ASSIGNMENT SHEET #8--CONSTRUCT INTERSECTIONS OF SURFACES

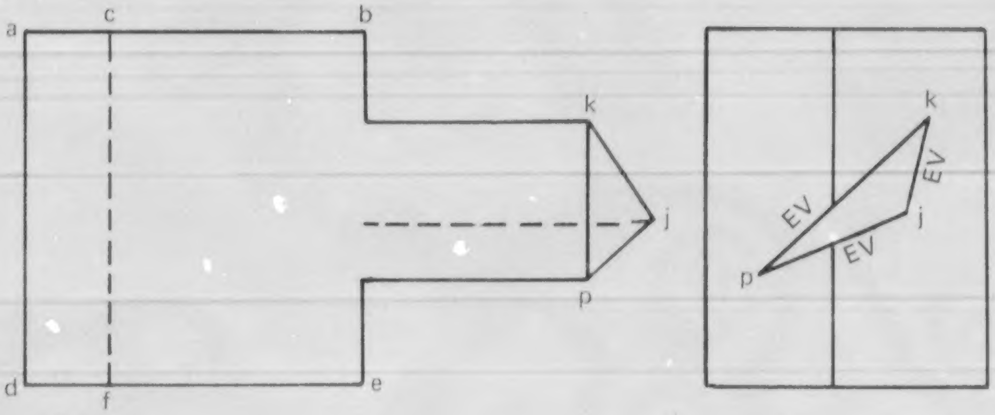
Directions: Construct intersections of surfaces using edge views. The procedure in the following example is to be used as a guideline for solving the prolems.

Example:

1. Identify and label all edge views (EV) and label all points

   (NOTE: If edge views are not given, use auxiliary views to find them.)



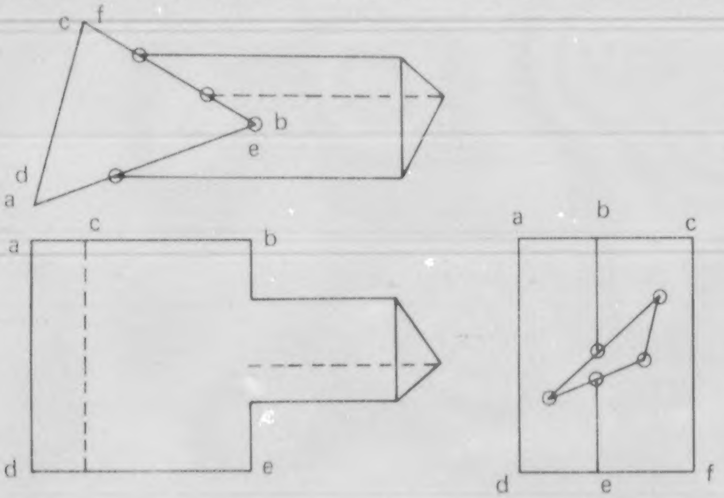


ASSIGNMENT SHEET #8

2. Observe edge views and circle points at the end of lines that intersect the edge views· these are called piercing points

   a. Since all three piercing points are not on the same plane, line "be" should also be circled to make the line of intersection continuous.

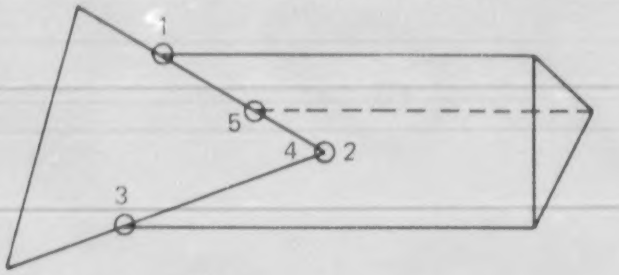
   b. Circle piercing points where "be" intersects the edges in the side view



3. Follow the line of intersection between the two objects numbering them as you go

   a. 1 and 2 are on the same top surface

   (NOTE: Point 5 is hidden and is on the bottom surface.)



   b. Line 2-3 is on the top surface

   c. Line 3-4 is on the bottom surface

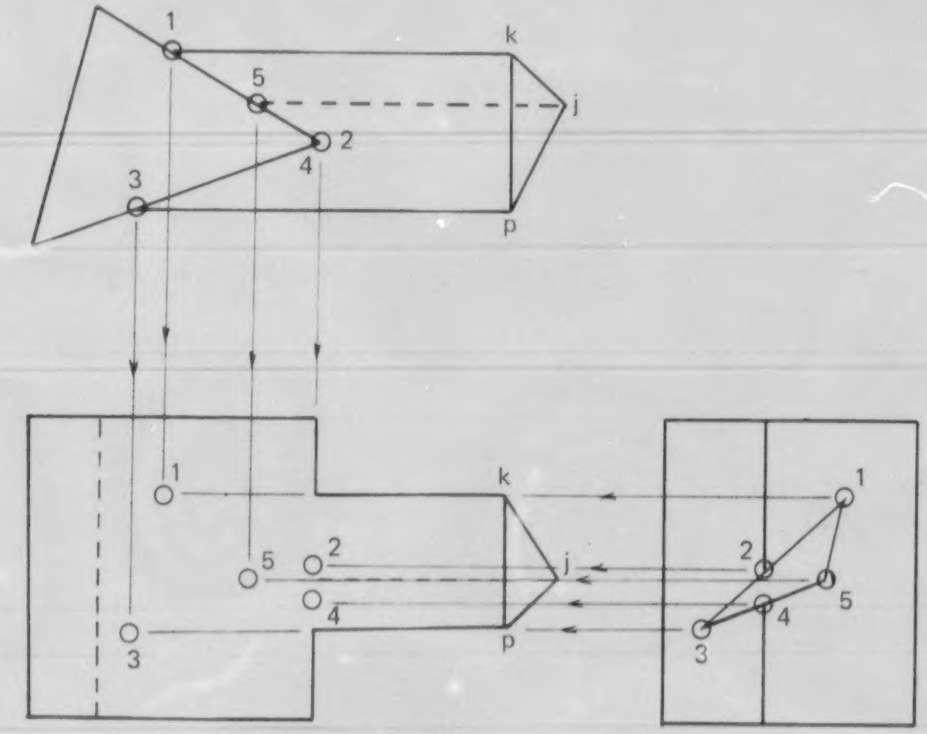
   d. Line 4-5 is on the bottom surface

   e. Line 5-1 is on the bottom surface

   f. The line of intersection is continuous ending with the same start point; your ability to visualize is very important in this process

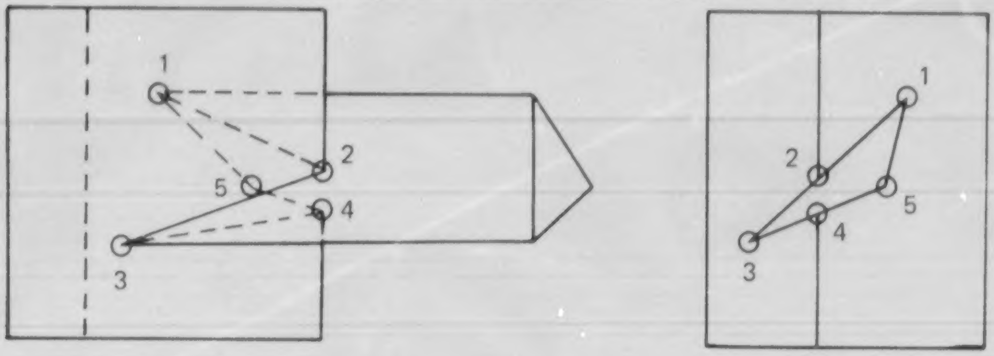
ASSIGNMENT SHEET #8

4. Project piercing points to front view intersecting corresponding lines; circle intersections



(NOTE: Points 2 and 4 must be projected from the side view. Another method for finding the piercing point of a line and a plane is the two-view method which will be covered in Assignment Sheet #9.)

5. Connect piercing points to form line of intersection; use visualizing skills to determine visibility and if lines are near the observer or far from the observer

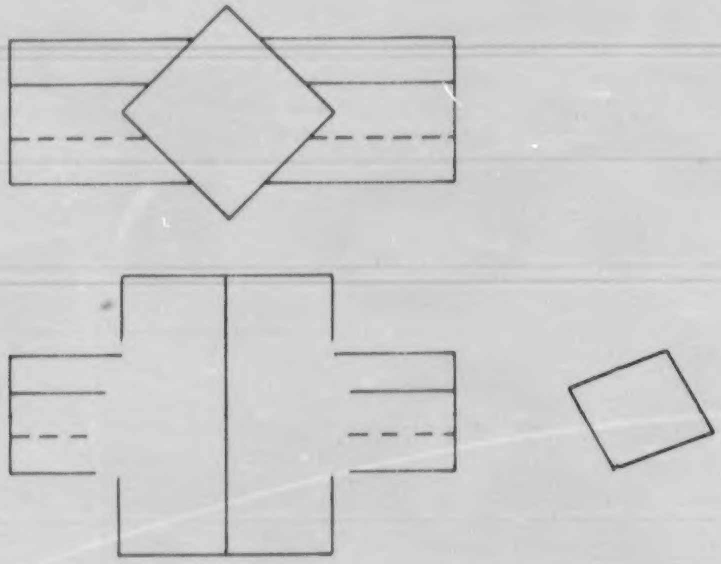


ASSIGNMENT SHEET #8

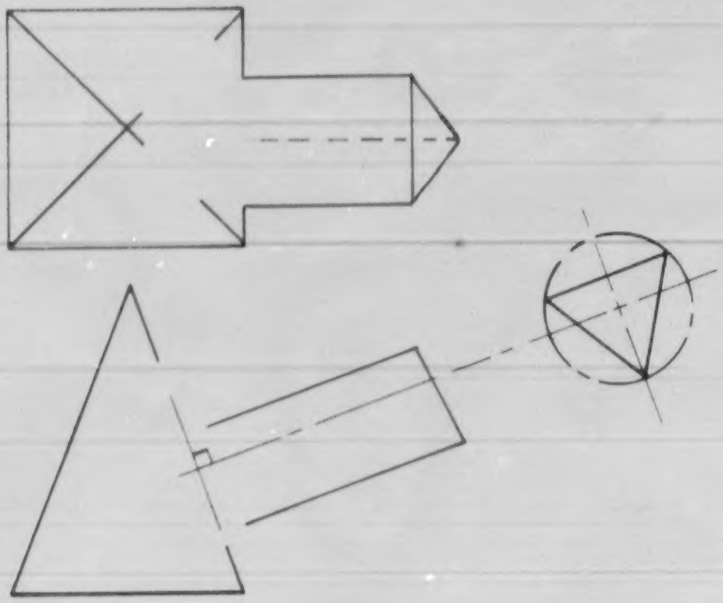
Problems:

Construct line of intersection between the parts shown. Circle piercing points and number line of intersection on all views.

A.

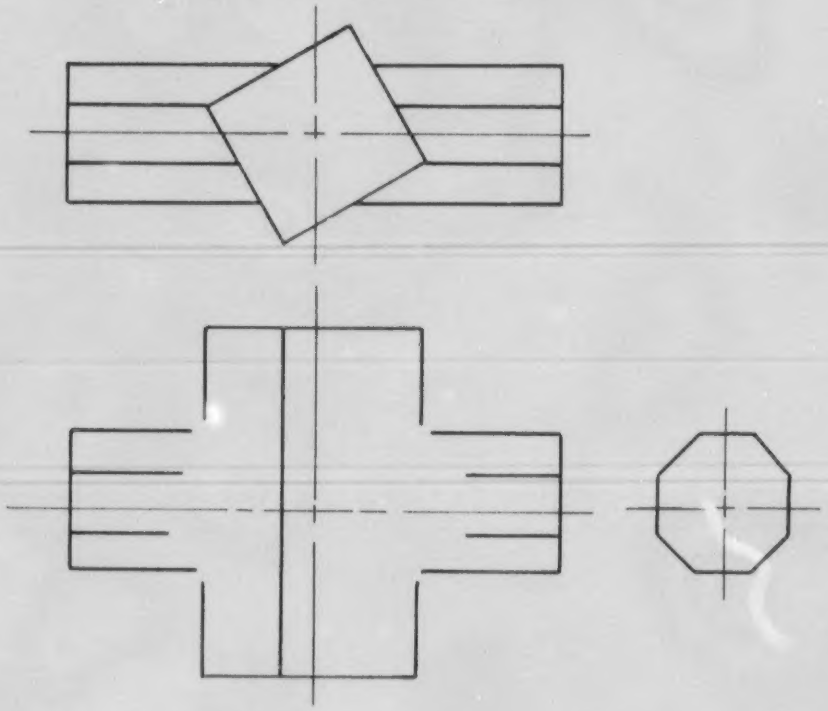


B.

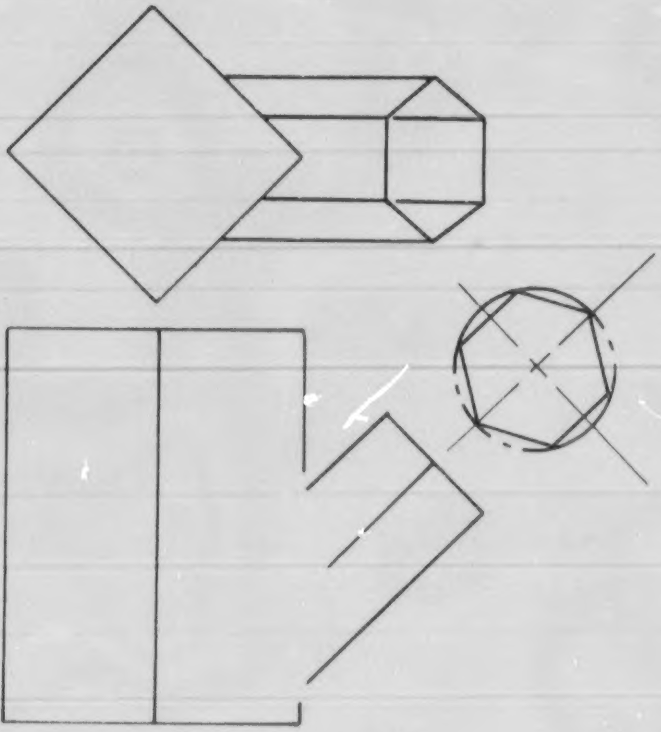


ASSIGNMENT SHEET #8

C.



D.



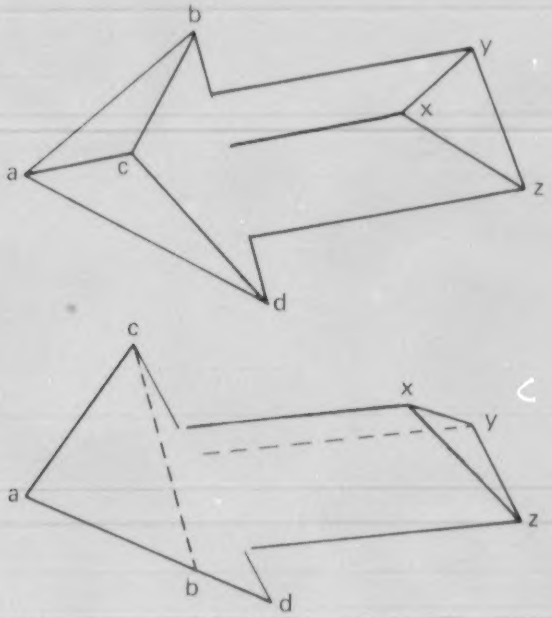
SHEET METAL DEVELOPMENTS
UNIT X

ASSIGNMENT SHEET #9--CONSTRUCT INTERSECTIONS OF SURFACES USING TWO-VIEW METHOD

Directions: Use the following example as a guideline for solving the problems of constructing intersections using the two-view method.

Example:

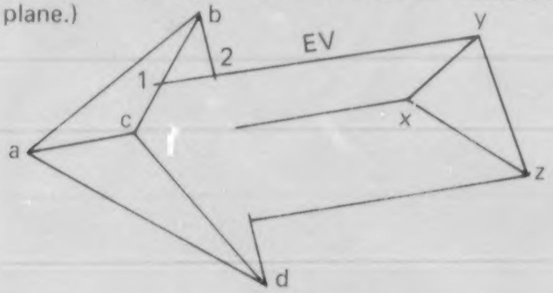
1. Identify and label all edge views if given and label all points



2. Take each line independently and locate its piercing point on the surface

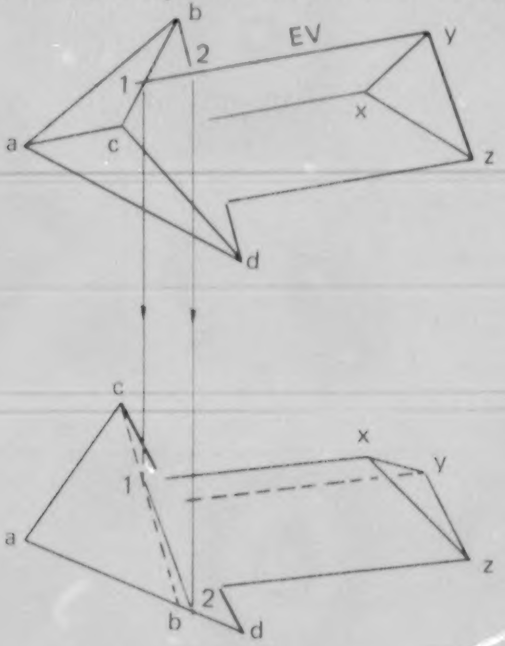
   a. Extend the line until it crosses two lines cb and bd on the plane you expect it to intersect; label intersections #1 and #2

   (NOTE: In this method, the line is marked EV to indicate the edge of an imaginary cutting plane.)

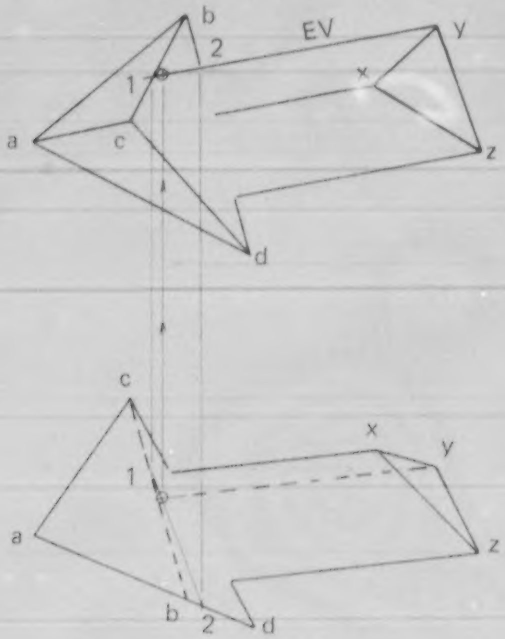


ASSIGNMENT SHEET #9

b. Project points 1 and 2 to adjacent front view to intersect lines cb and bd

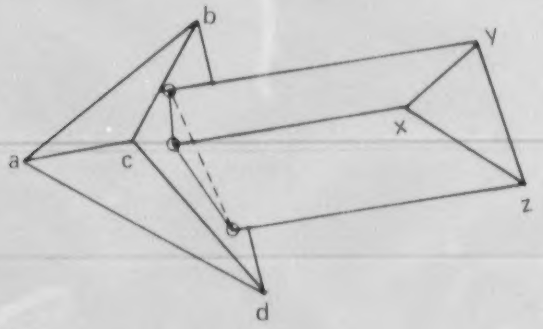

b
2
EV
y
1
x
a
c
z
d
c
x
y
1
a
z
2
b
d

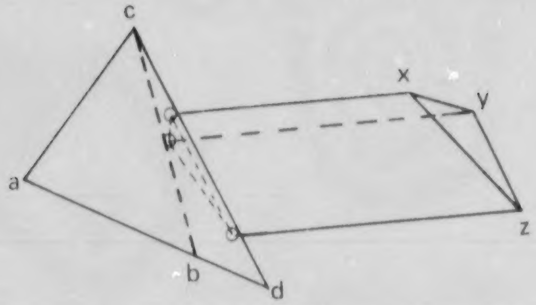
c. Draw a line between 1 and 2 where it intersects the line Y--that is a piercing point; mark piercing point, and project back to the one that we marked EV


b
EV
y
2
1
x
a
c
z
d
c
x
y
1
a
z
b
2
d

ASSIGNMENT SHEET #9

d. Use the same process to locate all piercing points



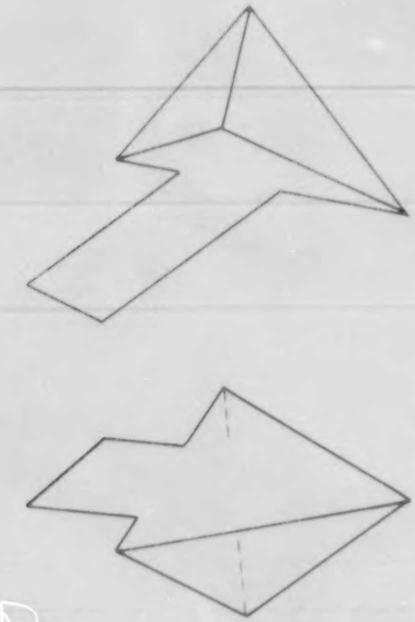


e. Connect piercing points to form line of intersection; use visualizing skills to determine visibility and if lines are near the observer or far from the observer

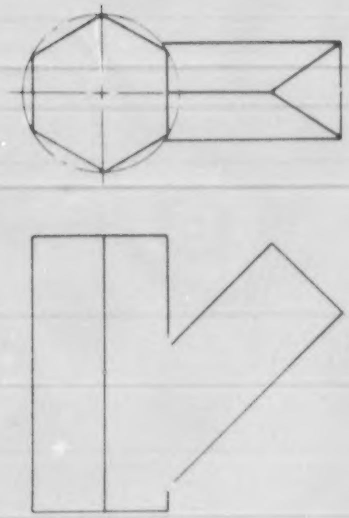
ASSIGNMENT SHEET #9

Problems: Construct line of intersection between the parts shown. Use two-view method where appropriate. Circle piercing points and number line of intersection on all views.

A.

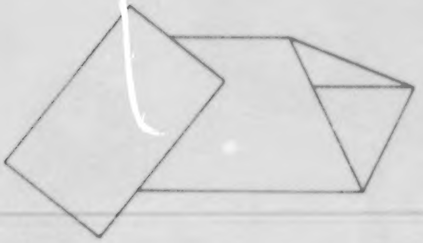


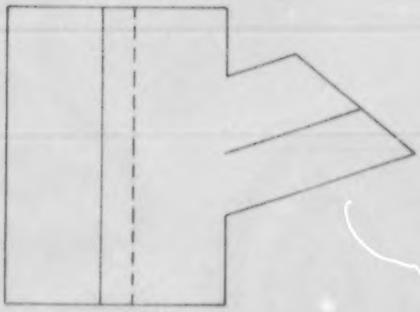
B.



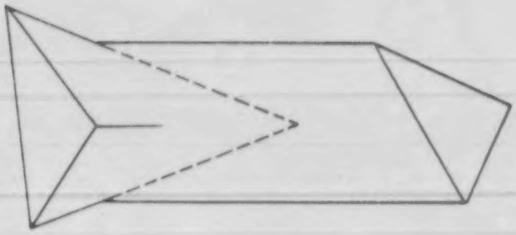
ASSIGNMENT SHEET #9

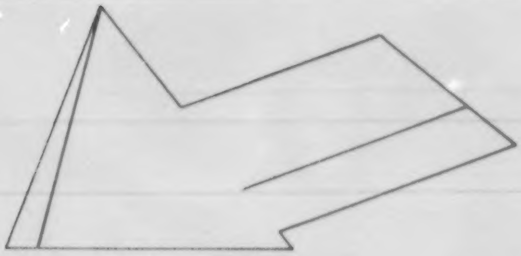
C.





D.





SHEET METAL DEVELOPMENTS
UNIT X

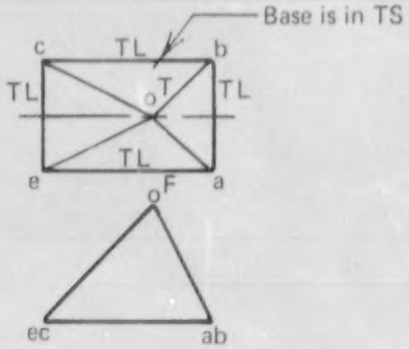
ASSIGNMENT SHEET #10–CONSTRUCT RADIAL LINE DEVELOPMENTS

Introduction: The objective of constructing sheet metal developments is to draw a true size flat pattern of the surface to be folded to the desired form. Edges are joined by seams, rivets, welding, soldering, and other means. Edge lengths should be kept to a minimum for economy and ease of handling. (Transparencies 19 and 20)

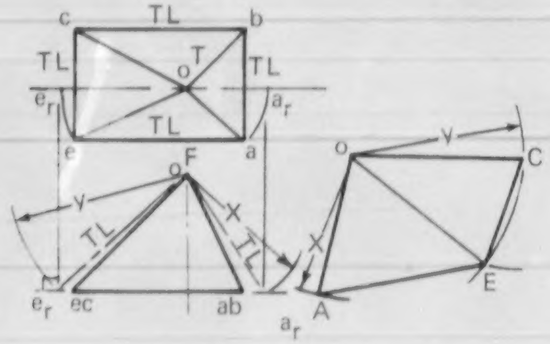
Directions: Construct radial line developments of pyramids, truncated pyramids, right circular cones, and oblique cones. An example is included for each of these.

Example A: Pyramids

1. Label all points, true length lines, and true size surfaces



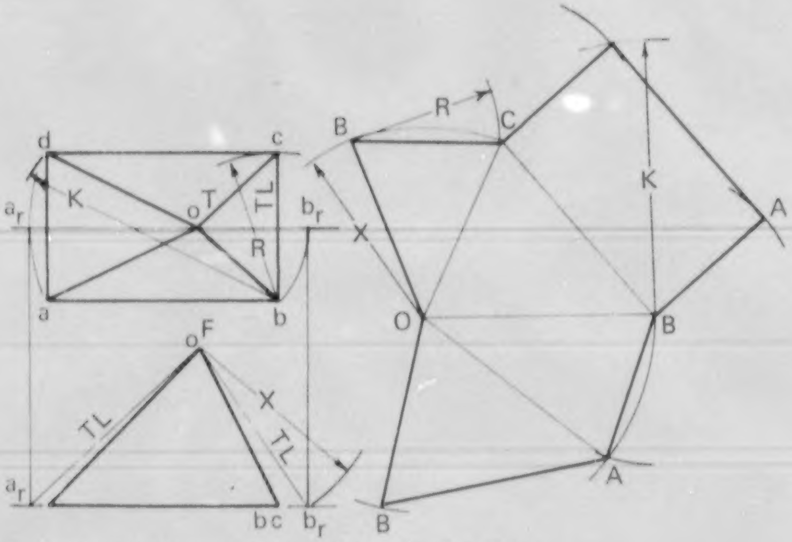
2. Find the true lengths of each inclined or oblique lines by rotation using the vertex as the axis



3. Decide where the seams will be located

4. Layout the surfaces in true size inside out

ASSIGNMENT SHEET #10

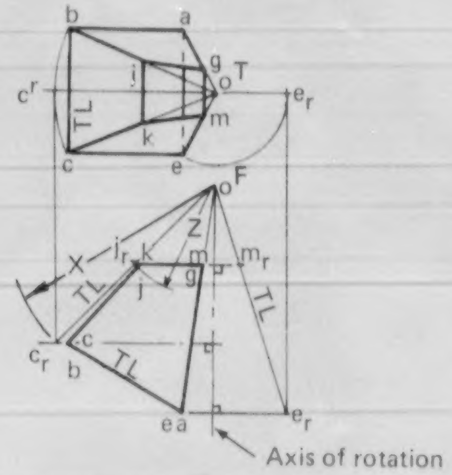

d
c
B
R
C
K
A
a_r
o
T
TL
b_r
X
R
a
b
O
B
F
X
TL
TL
a_r
b c
b_r
B
A

5. Complete the development making bend lines thin lines

   (NOTE: Notice the use of the diagonal distance "K" to transfer the rectangle.)

Example B: Truncated pyramids

1. Label all points, true length lines, and true size surfaces

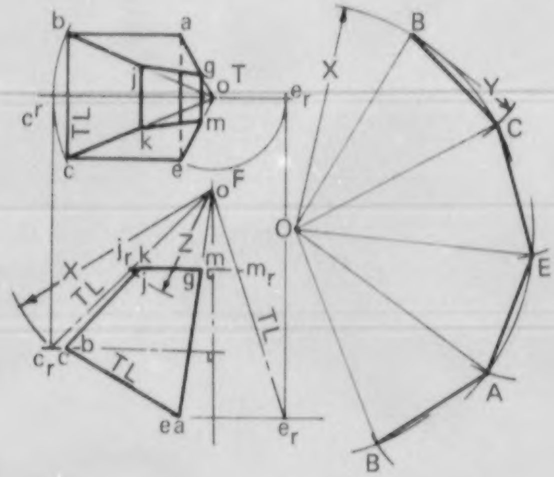

b
a
g
T
j
o
c^r
e_r
TL
m
k
c
e
F
Z
X
i_r
k
m
m_r
g
j
TL
TL
c_r
c
b
TL
e a
e_r
Axis of rotation

2. Find the true lengths of each inclined or oblique line by rotation using the vertex as center

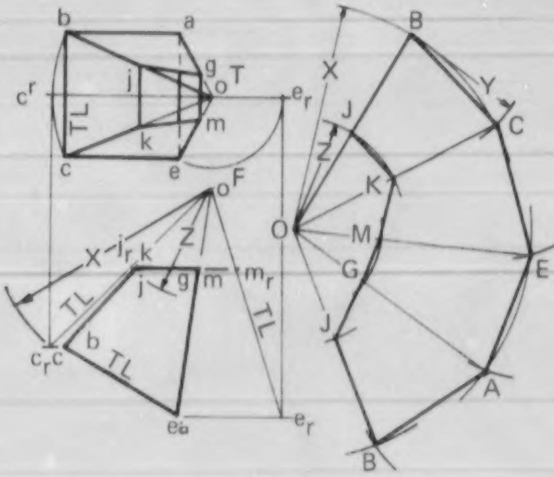
3. Since the object does not go to the vertex, project the intermediate distances perpendicular to the axis of rotation to obtain correct true lengths

ASSIGNMENT SHEET #10

4. In more complicated drawings a true length diagram is used to keep the drawing from becoming confusing


b
a
g
T
o
j
e_r
c^r
TL
m
k
c
e
F
o
O
X
Z
i_r
k
m
m_r
j
g
TL
TL
c_rc
b
TL
ea
e_r
B
Y
X
C
E
A
B

5. Layout the largest surfaces in true size inside up


b
a
g
T
o
j
c^r
e_r
TL
m
k
c
e
F
o
O
X
J
Z
K
M
G
J
X
i_r
k
j
g
m
m_r
TL
TL
c_rc
b
TL
ea
e_r
B
Y
C
E
A
B

6. Layout the smaller true lengths on the true length lines on the development

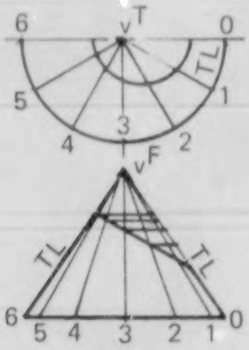
7. Complete the development making bend lines thin lines

ASSIGNMENT SHEET #10

Example C: Right circular cones

1. Label all points, true length lines, and true size surfaces

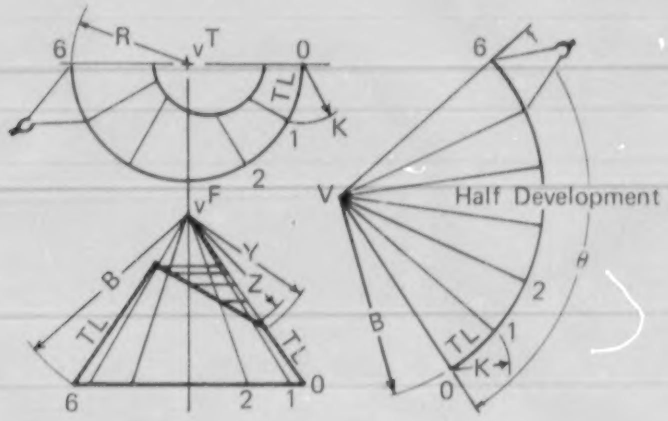
   (NOTE: This example does not have any true size surfaces.)


6
v T
0
TL
5
1
3
4
2
v F
TL
TL
6
5
4
3
2
1
0

   (NOTE: By observation, the base of the cylinder is in true size in the top view.)

2. Divide circular base into equal parts (normally every 15° or 30°) and draw the cone elements to the vertex; number each point

3. Project elements to the front view and draw to the vertex


R
6
v T
0
TL
K
1
2
v F
Y
B
Z
TL
TL
6
2
1
0
6
V
Half Development
θ
2
B
TL
1
K
0

4. Using the true length of the side of the cone as the radius, construct a semi-circle

ASSIGNMENT SHEET #10

5. Use the following formula to compute the number of degrees of the semi-circle for a half development

(NOTE: In this example, R = 10; B = 20.)

$$\theta = 1/2\left(\frac{R}{B}\ 360^\circ\right)$$

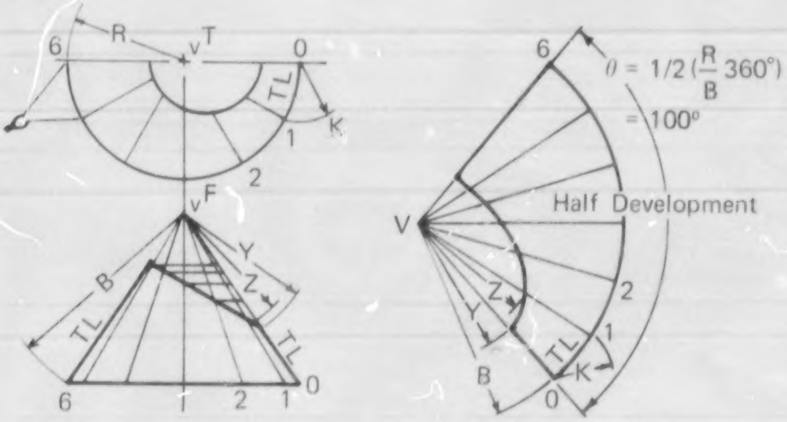
$$\theta = 1/2\left(\frac{10}{20}\ 360^\circ\right)$$

$$\theta = 90^\circ$$

(NOTE: When the formula is used, the elements must be stepped off with dividers to divide the arc equally.)

6. An alternate method, not as accurate, can be used

   a. Step the chord distance from 0 to 1, etc. around the semi-circle


6
R
vT
0
TL
K
1
2
vF
Y
Z
B
TL
TL
6
1
2
1
0
6
$\theta = 1/2\left(\frac{R}{B}\ 360^\circ\right)$
= 100°
Half Development
V
2
Z
Y
TL
1
K
B
0

   b. Construct the larger circle with a bow compass

   c. Layout the smaller true lengths on the developed true length lines

   d. Connect all points with an irregular curve

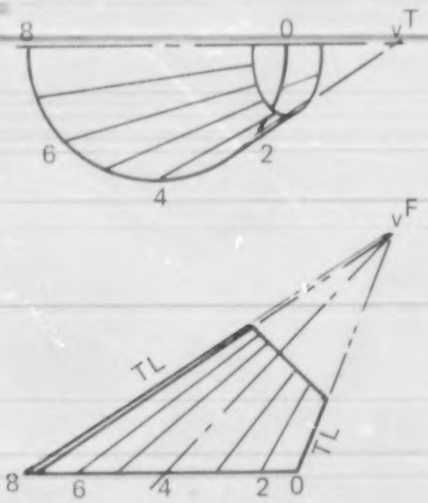
   e. Complete the development by darkening all lines

ASSIGNMENT SHEET #10

Example D: Oblique cones

1. Label all points, true length lines, and true size surfaces

   (NOTE: This example does not have any true size surfaces.)



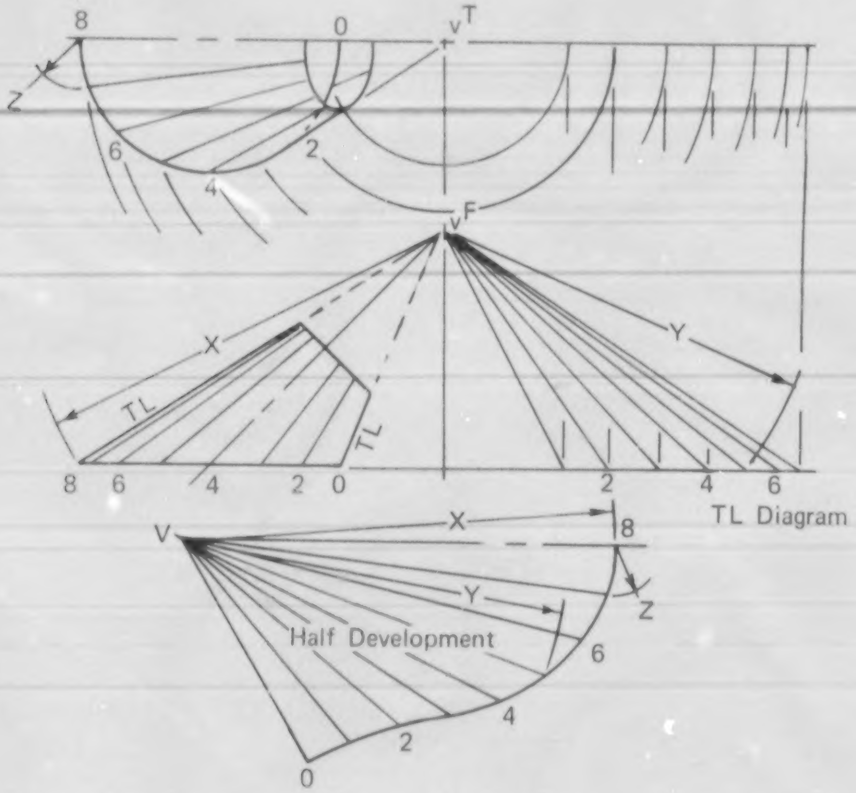
2. Divide circular base into equal parts and draw the cone elements to the vertex; number each point

3. Construct a true length diagram by rotating points on the right side of the drawing

   (NOTE: This helps to prevent confusion.)

ASSIGNMENT SHEET #10

4. Project all elements intersection of the inclined surface to the TL diagram; this will give the correct length for the cut

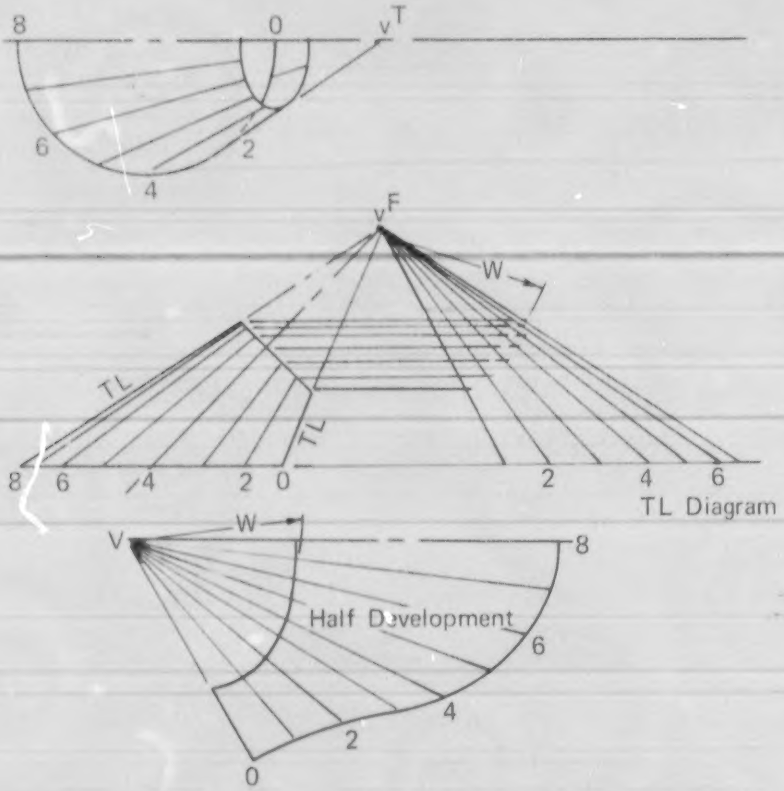

8
0
v T
Z
X
6
2
4
v F
X
TL
TL
Y
8
6
4
2
0
2
4
6
TL Diagram
V
X
8
Y
Z
Half Development
6
4
2
0

Half Development

5. Layout one true length element at a time and one circular radius between elements at a time

6. Connect all points using an irregular curve

ASSIGNMENT SHEET #10



Half Development

7. Layout the smaller true lengths on the developed true length lines

8. Connect all points with an irregular curve

9. Complete the development by darkening all lines

Problems:

1. Construct each problem on a "B" size sheet of vellum or other media selected by instructor. Draw both the two view drawing and the development. Add dimensions as instructed.

2. Make a blueline print of the drawing and cut the pattern out with scissors.

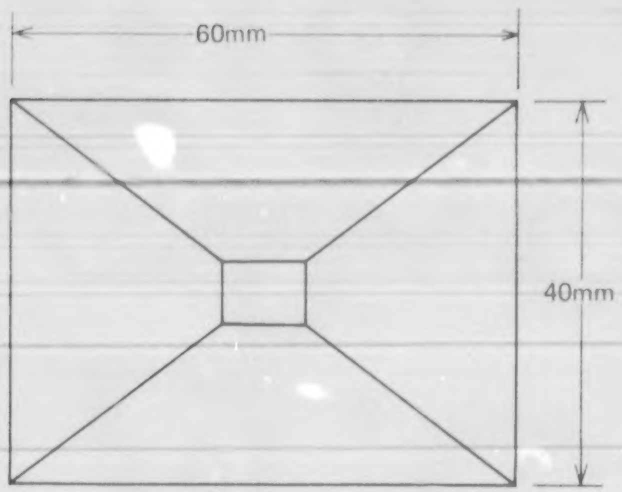
3. Tape or glue development together to form three dimensional part.

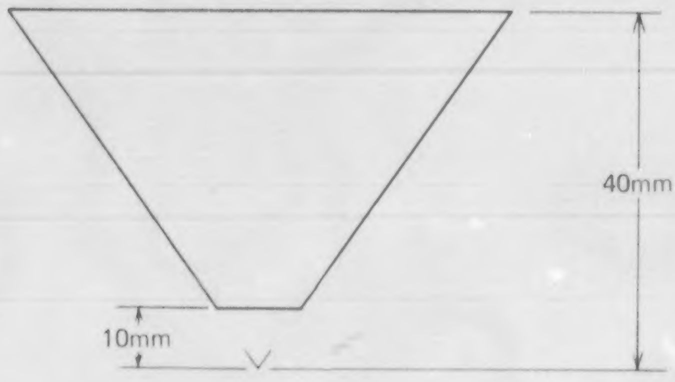
   (NOTE: This is a good time to check your work.)

4. Hand in both the original and the object to your instructor.

ASSIGNMENT SHEET #10

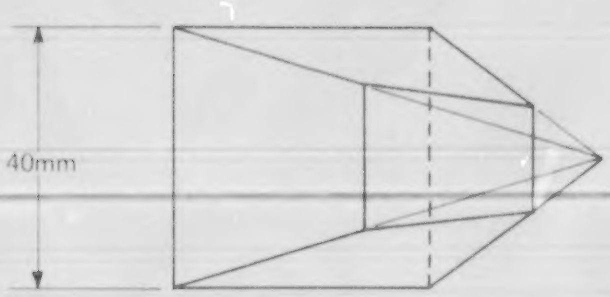
A.

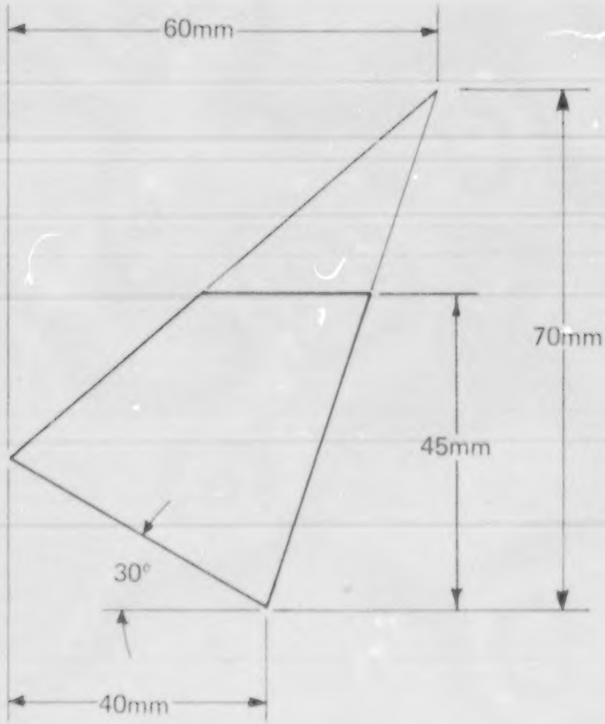




ASSIGNMENT SHEET #10

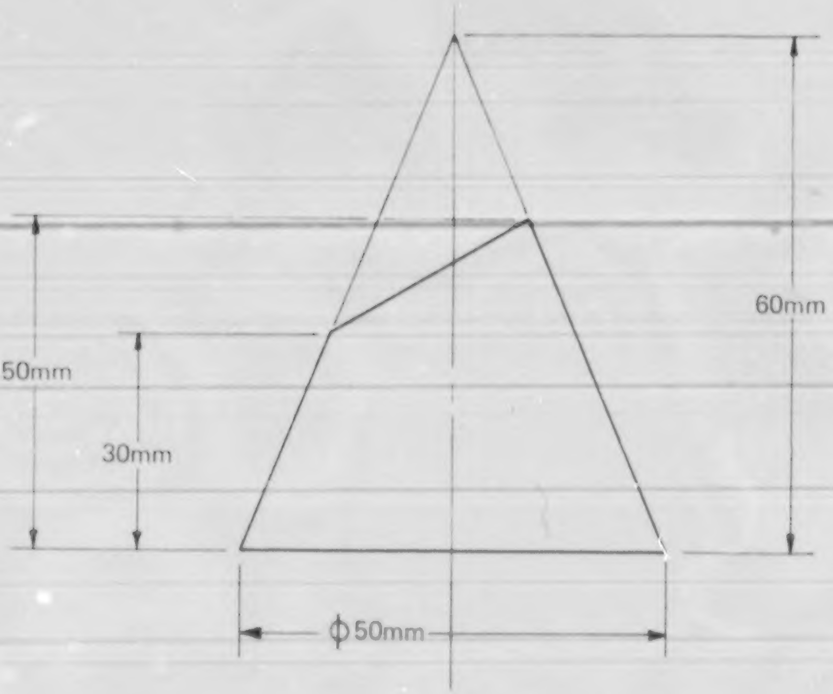
B.




60mm
70mm
45mm
30°
40mm

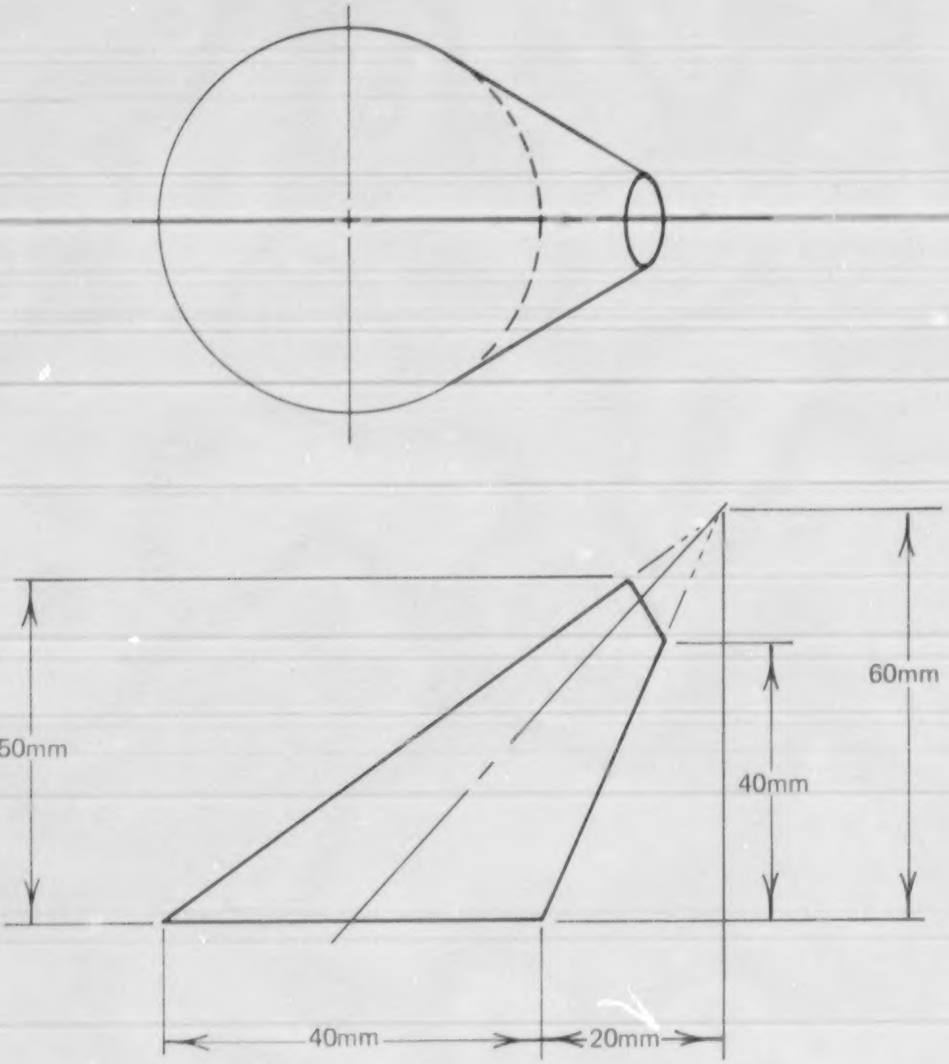
ASSIGNMENT SHEET #10

C.


60mm
50mm
30mm
ϕ50mm

ASSIGNMENT SHEET #10

D.


50mm
40mm
60mm
40mm
20mm

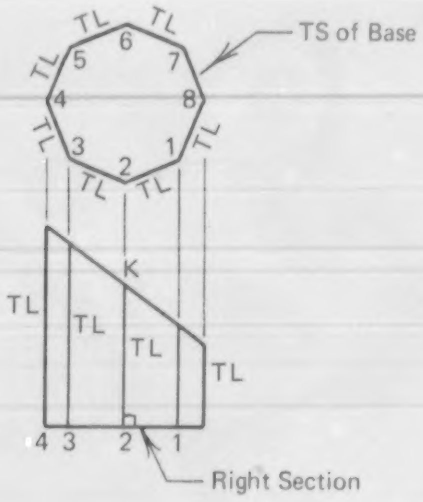
SHEET METAL DEVELOPMENTS
UNIT X

ASSIGNMENT SHEET #11--CONSTRUCT PARALLEL LINE DEVELOPMENTS

Directions: Construct parallel line developments of right prisms, oblique prisms, right circular cylinders, and oblique cylinders on "B" size media. Examples for each of these are included to be used as guidelines for solving the problems.

Example A: Right prisms

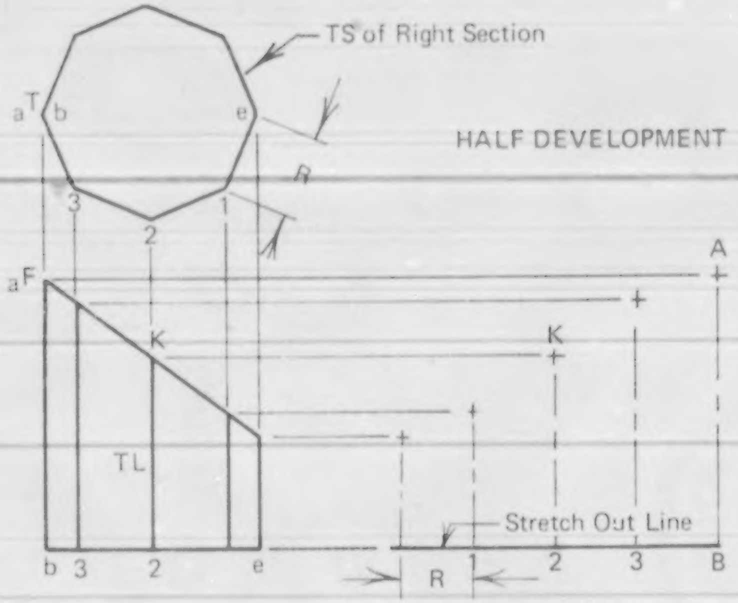
1. Label all points, true length lines, and true size surfaces



(NOTE: All lines are in true length except the inclined lines. Since the base is perpendicular to the octagon shaft, the corners formed on the planes are 90°. The top view is a right section of the base. When you have a right section, the solution to the problem is to transfer distances from the right section on a stretch out line.)

ASSIGNMENT SHEET #11

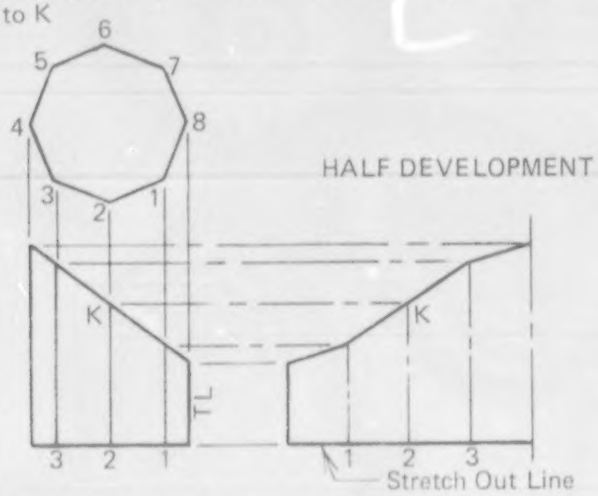
2. Project from the right section to the right hand area all true length vertical lines


TS of Right Section
aT
b
e
HALF DEVELOPMENT
R
3
2
1
aF
A
K
K
TL
Stretch Out Line
b 3 2 e
R
1 2 3 B

3. On the EV of the right section, mark off the true lengths of the base; this line is called a stretch out line

(NOTE: If a right section is not given, construct a right section perpendicular to the true length lines.)

4. Draw the lines from the points on the base until they connect to the common points such as 2 connects to K


6
5
7
4
8
HALF DEVELOPMENT
3
2
1
K
K
TL
3 2 1
1 2 3
Stretch Out Line

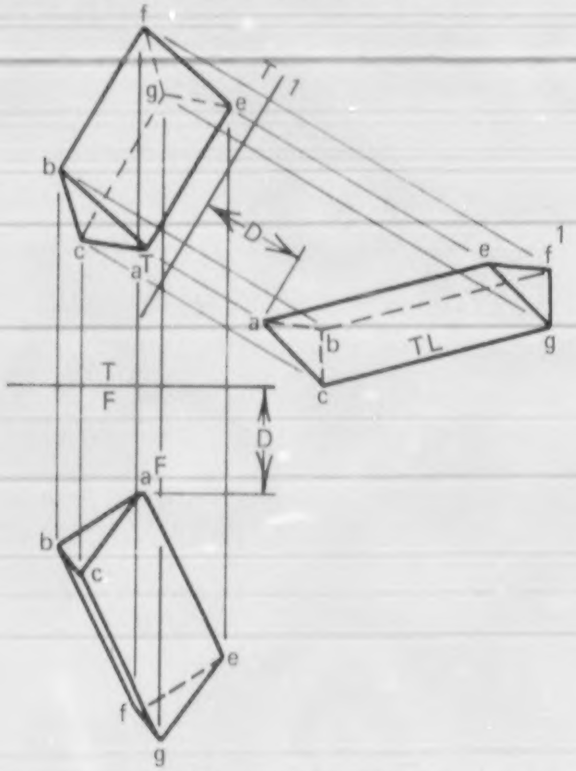
5. Complete the development making bend lines thin lines

ASSIGNMENT SHEET #11

Example B: Oblique prisms

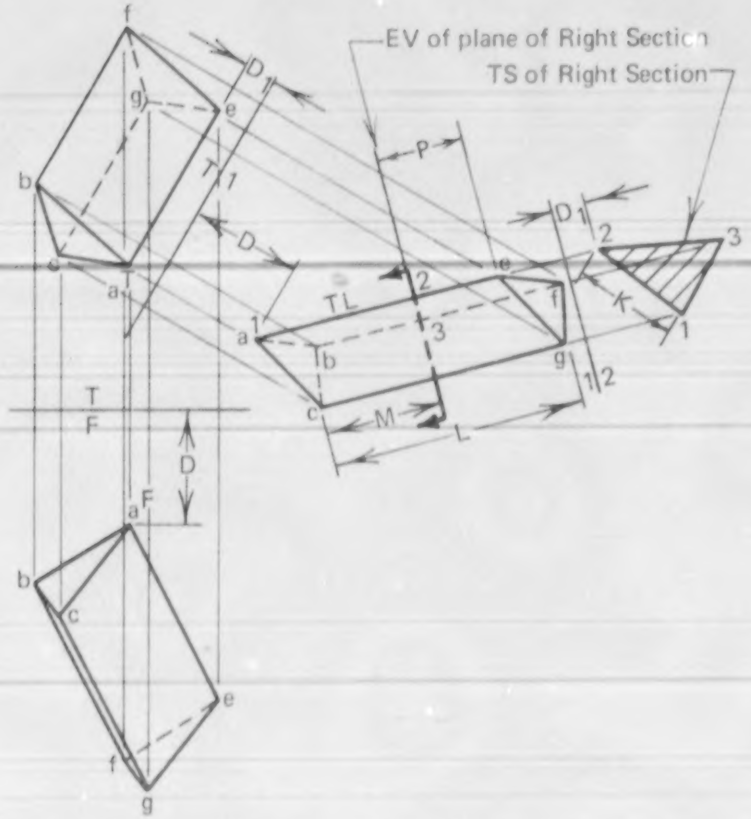
1. Label all points, true length lines, and true size surfaces

   (NOTE: This example has no true length lines or true size surfaces.)



2. To develop an oblique prism that has no true length sides given, construct an auxiliary view to find the true lengths of the parallel sides

ASSIGNMENT SHEET #11

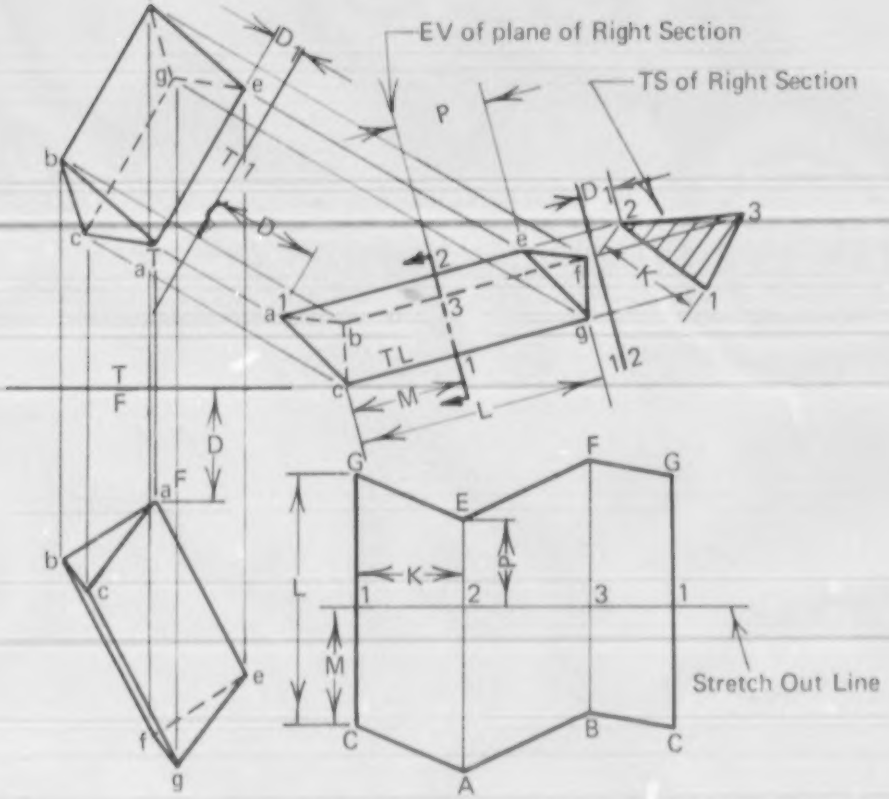

EV of plane of Right Section
TS of Right Section
f
g
e
b
c
a
D1
T1
D
P
D1
2
3
1
K
e
f
2
3
TL
a
1
b
g
1
2
c
M
L
T
F
D
a
F
b
c
e
f
g

3. Construct a true right section at a convenient location perpendicular to the TL of the parallel lines

   (NOTE: This view is an edge view of the section.)

4. Construct the true size of the right section by constructing the line of sight parallel to the true length lines

ASSIGNMENT SHEET #11


EV of plane of Right Section
TS of Right Section
Stretch Out Line
f
g
e
b
c
a
T
F
T
F
D
D
D_1
D_1
T_1
P
K
TL
M
L
1
2
3
G
E
F
G
1
2
3
1
C
A
B
C
K
P
L
M

5. In a convenient location draw a horizontal stretch out line

6. Transfer the true lengths of the sides from the TS right section view

7. Construct vertical lines through the points

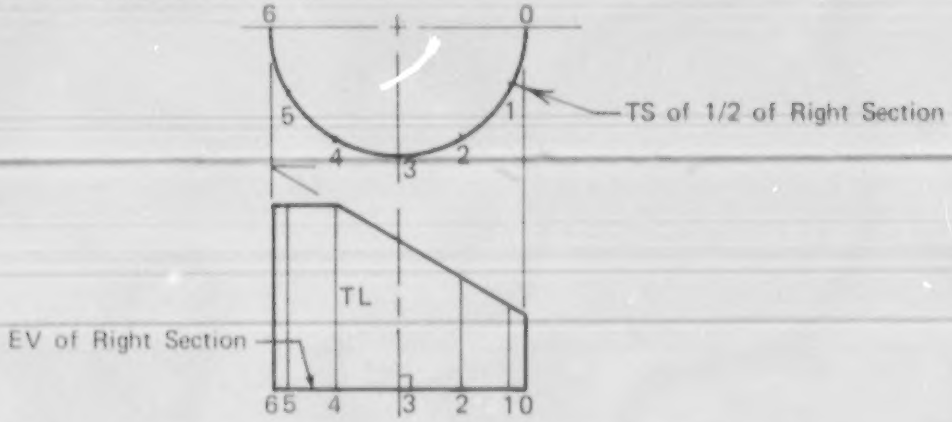
8. Transfer true lengths of sides from the EV of the right section to the vertical lines

9. Complete the development making bend lines thin lines

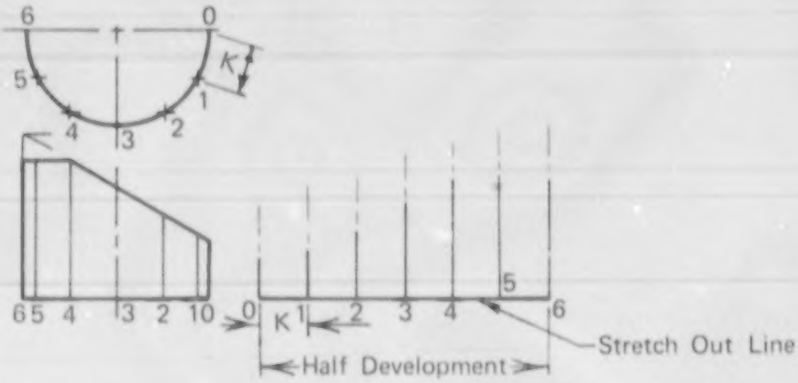
ASSIGNMENT SHEET #11

Example C: Right circular cylinders

1. Label all points, true length lines, and true size surfaces


6
0
5
1
4
3
2
TS of 1/2 of Right Section
TL
EV of Right Section
6 5 4 3 2 1 0

2. By observation, the base of the cylinder is in true size in the top view
3. Divide circular base into equal parts (normally every 15° or 30°)
4. Project points (actually end view of elements) to front view and draw the elements parallel to the center line

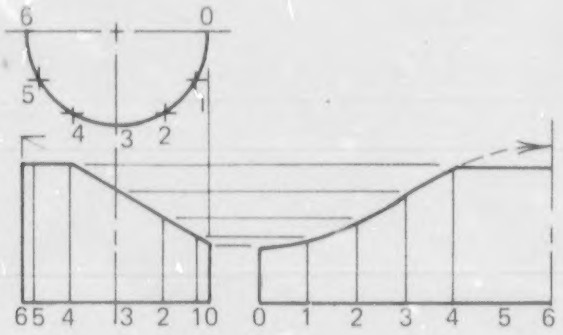

6
0
K
5
1
4
3
2
6 5 4 3 2 1 0
0 K 1 2 3 4 5 6
Stretch Out Line
Half Development

5. Project horizontal stretch out line from EV of right section
6. Transfer distances from top view from point 0 - 1 to stretch out line

   (NOTE: The distance laid out is 1/2 circumference.)

ASSIGNMENT SHEET #11

7. Project vertical lines from each point on stretch out line

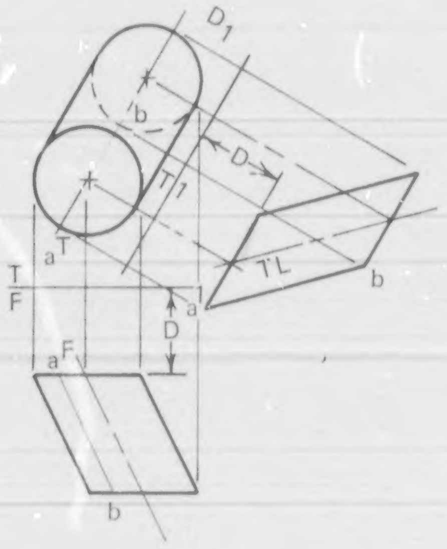


8. Project points from inclined top edge of elements in front view to corresponding elements in development area

9. Complete the developments by connecting points with an irregular curve

Example D: Oblique cylinders

1. Label all points, true length lines, and true size surfaces



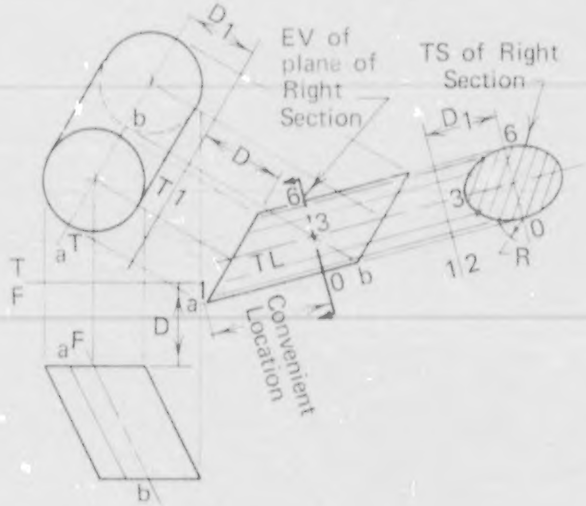
2. To develop an oblique prism that has no true length center line given, construct an auxiliary view to find the true length of the center line

ASSIGNMENT SHEET #11

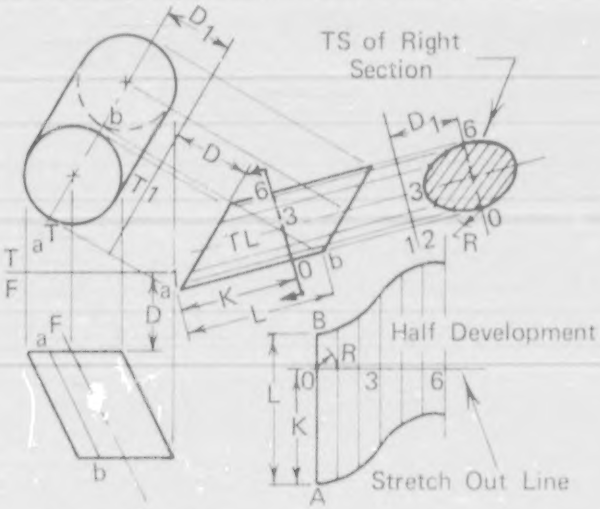
3. Construct a true right section at a convenient location perpendicular to the TL of the center line

   (NOTE: This view is an edge view of the section.)

4. Construct the true size of the right section by constructing the line of sight parallel to the TL of the center line


D1
EV of plane of Right Section
TS of Right Section
D1
6
b
D
6
3
3
T1
0
aT
TL
R
T
F
1 2
0 b
1
a
D
Convenient Location
aF
b

5. Divide the ellipse right section into equal parts and project back to view with TL center line; these lines are elements of the cylinder and are in TL


D1
TS of Right Section
b
D1
6
D
6
3
T1
3
aT
TL
1 2
R
0
T
F
0 b
a
K
L
B
D
Half Development
aF
R
0
3
6
L
K
b
A
Stretch Out Line

ASSIGNMENT SHEET #11

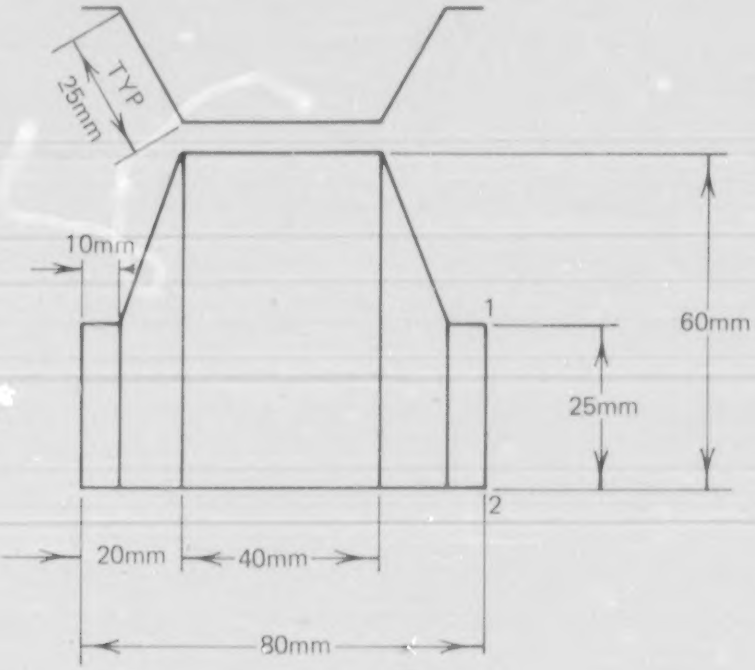
6. In a convenient location, draw a horizontal stretch out line
7. Transfer the distances between the point view of the elements in the TS right section view to the stretch out line
8. Project vertical lines from each point on the stretch out line
9. Transfer TL of elements from the EV of the right section to the vertical lines
10. Complete the view using an irregular curve

Problems:

1. Construct a development for each problem on a "B" size sheet of vellum or other media selected by instructor. Draw both the two view drawing with all construction lines and the development. Add dimensions as required by instructor.
2. Make a blueline print of the drawing and cut the pattern out with scissors.
3. Tape or glue development together to form three dimensional part.

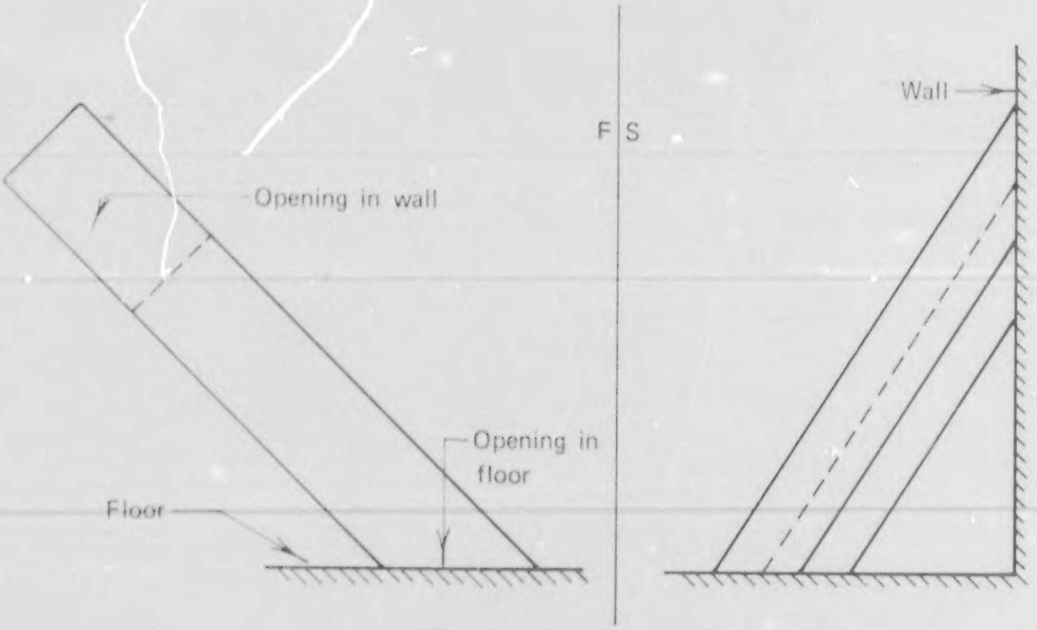
   (NOTE: This is a good time to check your work.)
4. Hand in both the original and the object to your instructor.

A.

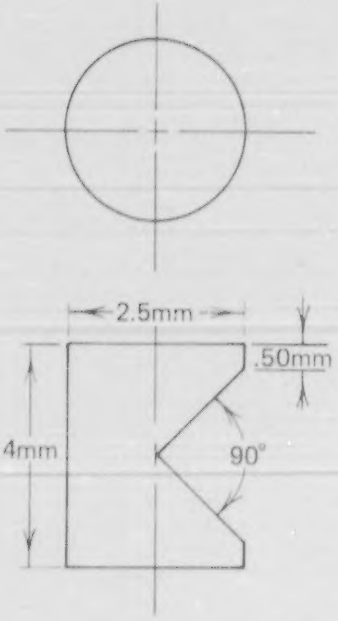


ASSIGNMENT SHEET #11

B. Transfer dimensions to "B" size media. Part is inclined at an angle of 25° to wall.

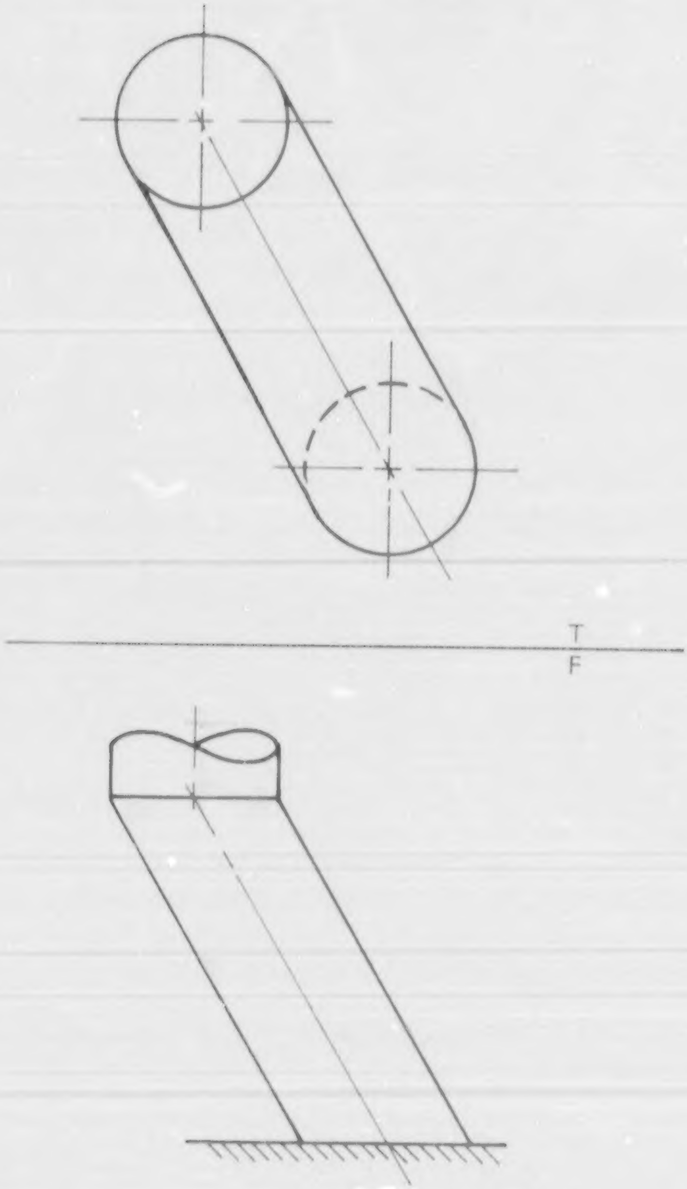

Opening in wall
Opening in floor
Floor
F
S
Wall

C


2.5mm
.50mm
4mm
90°

ASSIGNMENT SHEET #11

D.



SHEET METAL DEVELOPMENTS
UNIT X

ASSIGNMENT SHEET #12–CONSTRUCT SPECIAL DEVELOPMENTS USING TRIANGULATION

Introduction: Many surfaces cannot be developed by the radial line or parallel line methods. Some of these other surfaces can be developed or approximately developed using triangulation. As the name triangulation implies, this method divides surfaces into triangles which can be easily constructed. (Transparency 22)

Example: Is this four sided figure ABCD a flat plane? It looks to be, but when we examine the diagonal lines, we find they do not intersect!

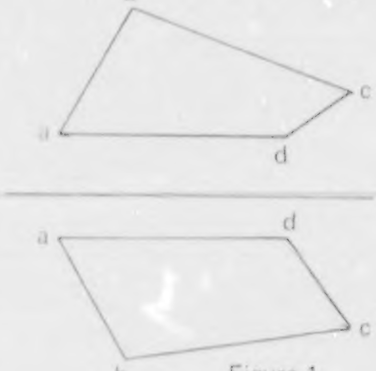


Figure 1

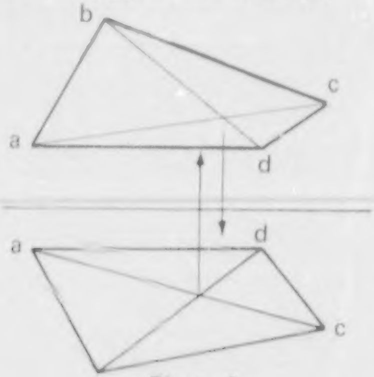
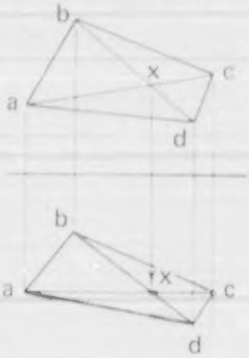


Figure 2

The plane constructed in Figure 1 is not a true flat plane but is, in fact, a warped plane.

To construct a four or more sided plane, we must first divide the surface into triangles, then project the triangles to the adjacent view including the intersection of the diagonals. Line ax is extended to locate point C. The resulting four sided figure is a flat plane.



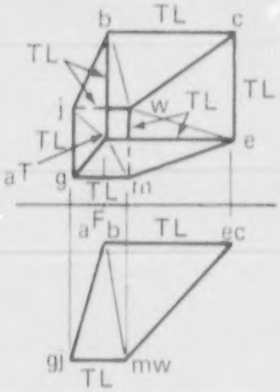
This concept is important when constructing drawings. The optical illusion of a flat plane with four or more sides is easy to draw. Always construct oblique planes with three or more sides using this triangulation method.

ASSIGNMENT SHEET #12

Directions: Construct plane surfaces and transition pieces using triangulation on "B" size media. Examples are included to be used as guidelines for solving the problems.

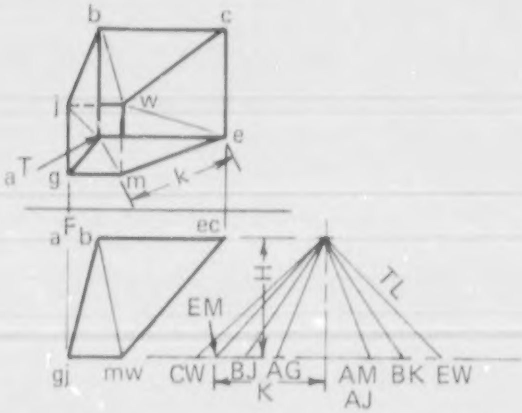
Example A: Plane surfaces by triangulation

1. Label all points, true length lines, and true size surfaces


b
TL
c
TL
TL
j
w
TL
TL
e
TL
a T
g
TL
m
a F
b
TL
ec
gj
TL
mw

(NOTE: This plane surface hopper is not part of a pyramid and cannot be developed using radial line or parallel line methods.)

2. Divide each surface into triangles


b
c
j
w
e
a T
g
m
k
a F
b
ec
H
EM
TL
gj
mw
CW
BJ
AG
K
AM
AJ
BK
EW

TL Diagram

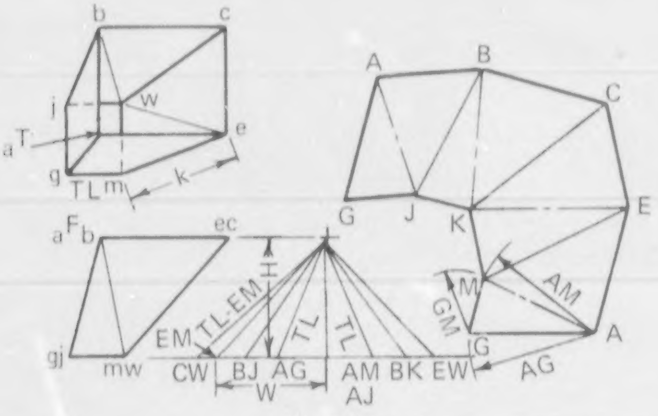
3. Set up a true length diagram next to the front view to prevent confusion in the front view

4. Project the height (H) directly to the true length diagram; this is the same as saying, project the edge view of the path of rotation

ASSIGNMENT SHEET #12

5. Transfer directly to the true length diagram the distance (W) that is normally rotated until it is parallel to the folding line

6. Label all lines correctly on the TL diagram for future use


b
c
j
w
a^T
e
g
TL m
k
A
B
C
G
J
K
E
a^F b
ec
H
TL-EM
TL
TL
EM
M
AM
GM
G
A
gj
mw
CW
BJ
AG
AM
AJ
BK
EW
AG
W

TL Diagram

7. Select an open area on the drawing to start the development; allow lots of space

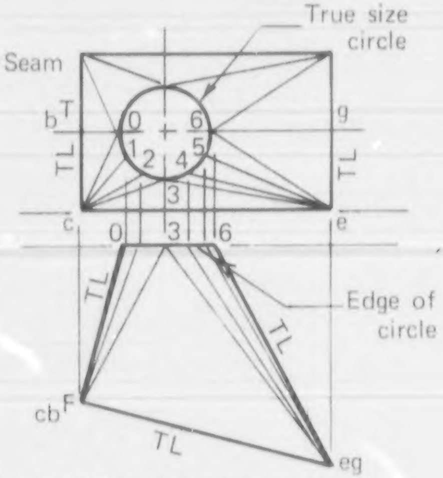
8. Take true length dimensions of each triangle from those given and those of the TL diagram

9. Construct the triangles forming the sides of the surfaces; always start with the shortest side

10. Complete the development adding bend lines

Example B: Transition piece by triangulation

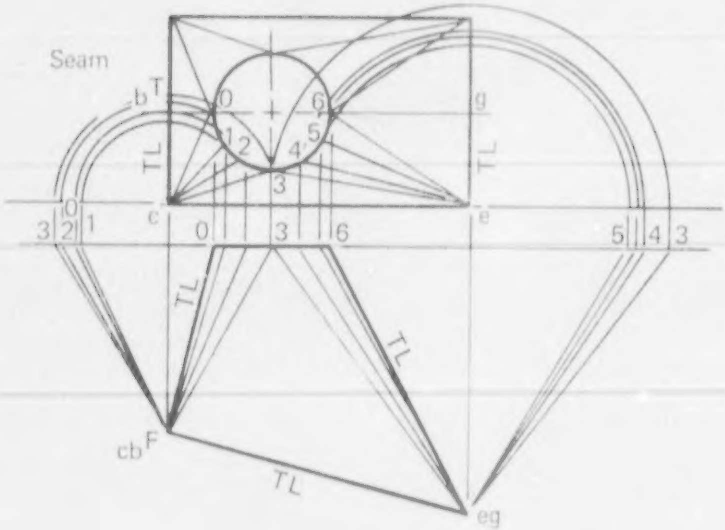
1. Label all points, true length lines, and true sizes


True size circle
Seam
b^T
0
6
g
1
2
4
5
TL
TL
3
c
0
3
6
e
TL
Edge of circle
TL
cb^F
TL
eg

(NOTE: This transition piece goes from a circular part to a rectangular part.)

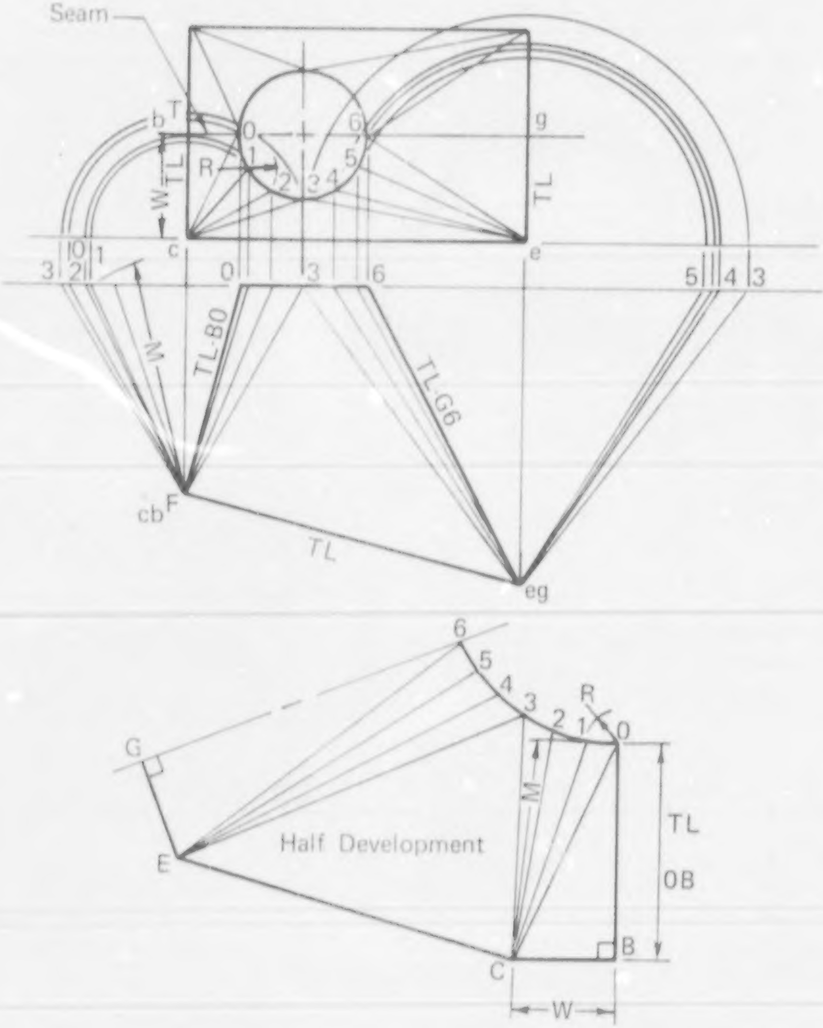
ASSIGNMENT SHEET #12

2. Divide the circle into equal parts (normally 15° to 30° increments).
3. Draw common elements in both views forming triangle surfaces from the circle to the rectangle
4. Observe the number of true lengths that must be found


Seam
bT
0
6
g
TL
1
2
4
5
TL
3
c
e
3
2
0
1
0
3
6
5
4
3
TL
TL
cbF
TL
eg

5. Determine where seam will be; this should be the shortest connection
6. Construct TL of all elements by using a TL diagram or other means

ASSIGNMENT SHEET #12


Seam
b
T
TL
W
R
0
1
2
3
4
5
6
g
TL
c
e
3
2
0
1
0
3
6
5
4
3
M
TL-B0
TL-G6
cb F
TL
eg
6
5
4
3
2
R
1
0
G
M
TL
Half Development
E
0B
B
C
W

7. Select an open area to start the development

8. Starting with the seam, develop inside out by constructing triangles of each surface

9. Take true length dimensions of each triangle from the chord distance on the circle, those TL given, and those found on the TL diagram

10. Complete the development adding bend lines

ASSIGNMENT SHEET #12

Problems:

1. Construct each problem on a "B" size sheet of vellum or other media selected by instructor. Draw both the two view drawing and the development. Add dimensions as instructed.

2. Make a blueline print of the drawings and cut the pattern out with scissors.

   (NOTE: Half patterns will need to be doubled.)

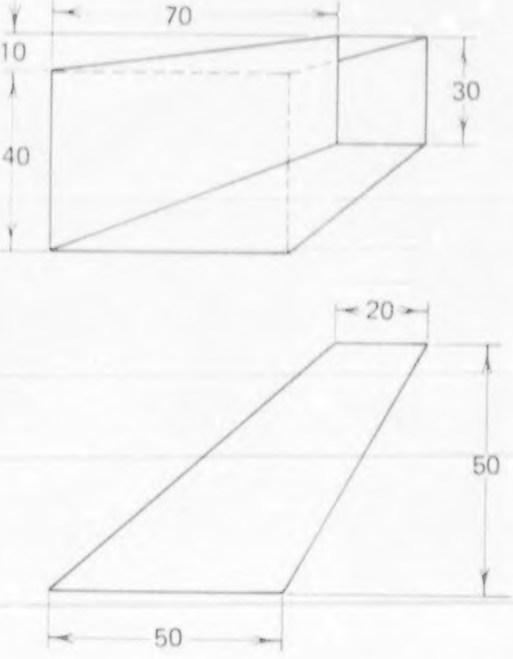
3. Tape or glue development together to form three dimensional part.

   (NOTE: This is a good time to check your work.)

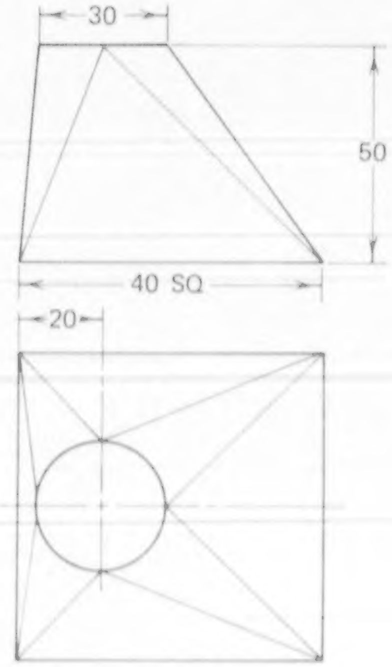
4. Hand in both the original and the object to your instructor.

ASSIGNMENT SHEET #12

A.

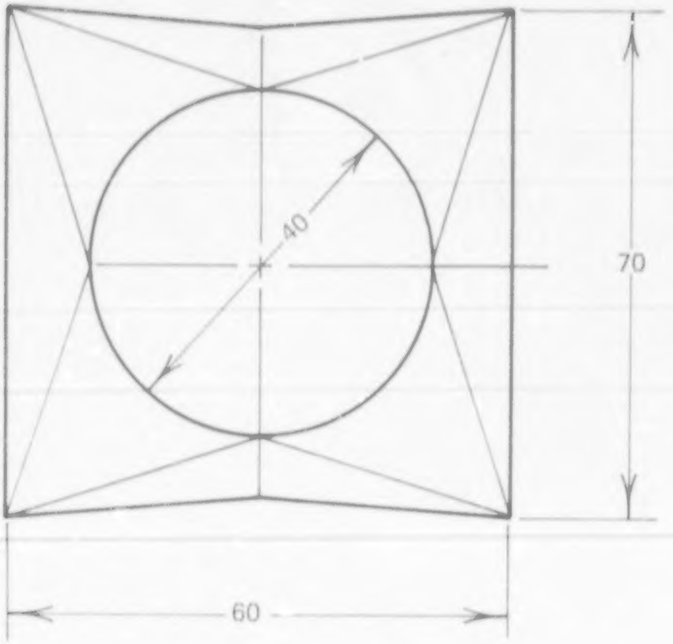

70
10
40
30
20
50
50

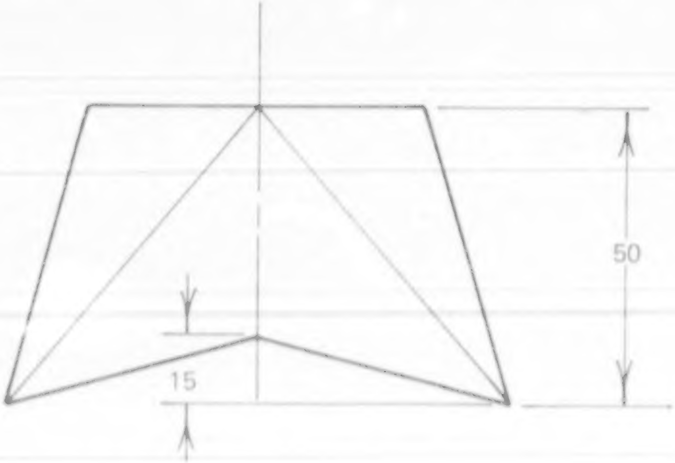
B.


30
50
40 SQ
20

ASSIGNMENT SHEET #12

C.





SHEET METAL DEVELOPMENTS
UNIT X

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

The labeling of all problems should be evaluated to the satisfaction of the instructor

A. 1. 12
 2. abcdef

B. 1. yzvj, abcdef, klmnop, ghdc
 2. Yes
 3. Normal
 4. Inclined

C, D Evaluated to the satisfaction of the instructor

Assignment Sheet #2

A.

LINE	VIEW TL IS LOCATED	NON-TL	TYPE OF LINE		
			NORMAL	INCLINED	OBLIQUE
ab	Top & Side	--	X		
cd	Top & Side	--	X		
hc	Front	Top & Side		X	
ef	Side	Front & Top		X	
nf	Top & Front	--	X		
oj	Front & Side	--	X		
gf	Top & Side	--	X		
hi	Top & Side	--	X		
id	Front	Top & Side		X	
ein	Front & Top	--	X		
lm	Top & Side	--	X		
og	Top & Front	--	X		

B.

LINE	VIEW TL IS LOCATED	NON-TL	TYPE OF LINE		
			NORMAL	INCLINED	OBLIQUE
cb	Top	Front & Side		X	
go	Front & Side	--	X		
he	--	Top, Front, & Side			X
fg	Front & Side	--	X		
fb	--	Top, Front, & Side			X
ab	Top & Front	--	X		
gb	Side	Top & Front		X	
hi	Top & Side	--	X		
tu	Top & Side	--	X		

Assignment Sheet #3

A.

PLANE	VIEW TS IS LOCATED	VIEW NON-TS IS LOCATED	VIEW EDGE VIEW IS LOCATED	TYPE OF PLANE		
				NORMAL	INCLINED	OBLIQUE
cbf	--	Front & Side	Top		X	
abcde	Top	--	Front & Side	X		
deh	--	Front & Side	Top		X	
tmlu	Top	--	Top & Side	X		
bfg	--	Top & Front	Side		X	

B.

PLANE	VIEW TS IS LOCATED	VIEW NON-TS IS LOCATED	VIEW EDGE VIEW IS LOCATED	TYPE OF PLANE		
				NORMAL	INCLINED	OBLIQUE
abcde	Top	--	Front & Side	X		
bgfc	--	Top & Side	Front		X	
rst	Front	--	Top & Side	X		
mpni	Top	--	Front & Side	X		
end	--	Top, Front, & Side	--			X

(NOTE: All other assignment sheets are to be evaluated to the satisfaction of the instructor.)

SHEET METAL DEVELOPMENTS
UNIT X

NAME ________________________________

TEST

1. Match the terms on the right with the correct definitions.

______a. The exact measurable view of the exact length of a line found by observation, projection, or calculation

______b. The exact measurable view of the exact size of a surface found by observation, projection, or calculation

______c. A pattern of the true sizes of unfolded or unrolled surfaces arranged to be folded to the desired shape

______d. An additional amount of material necessary when making a bend

______e. The development of objects that can be developed due to elements radiating from a single point or vertex

______f. The development of objects that can be developed due to parallel elements on these surfaces

______g. A method of developing surfaces not possible by the parallel line or radial line methods

______h. A ruled surface that cannot be developed

______i. A cutting plane perpendicular to an axis of a three dimensional form

______j. A diagram of the true lengths projected from the normal views

______k. Ruled lines on the surface of geometric shapes

______l. A surface which has no straight line elements and cannot be developed

______m. Any surface generated by straight lines

______n. A ruled surface generated by a straight line that can be developed

______o. The intersection of a circular cone and a plane

1. Mold line
2. Radial line development
3. Double curved surface
4. Transition piece
5. Folding line
6. True length diagram
7. Shrink templates
8. Bend line
9. Rotation
10. True size of a surface
11. Single curved surface
12. Development
13. Right section
14. Triangulation
15. Stretch out line

______ p. A line that is perpendicular to each element on which a parallel line development is unrolled or unfolded

______ q. A piece that connects two differently shaped conductors

______ r. Original and complete developments of parts used for reference and checking

______ s. Contour templates made with a shrink scale for die maker and foundry

______ t. Templates to exact contour of part used for checking parts at production stages

______ u. Where bend starts

______ v. The intersection of two adjacent surfaces

______ w. Drilled or routed holes at intersection of bends to relieve strain which would cause metal to crack or buckle

______ x. A method of projection in which the observer stays stationary and the object is rotated for different views of the object

______ y. A reference line normally between two views representing the edge of a plane of projection

16. Bend allowance
17. True length of a line
18. Relief holes
19. Elements of a surface
20. Ruled surface
21. Contour templates
22. Parallel line development
23. Conic section
24. Master layouts
25. Warped surface

2. Distinguish between visualization of near and far points and planes by placing an "X" next to the near points and planes.

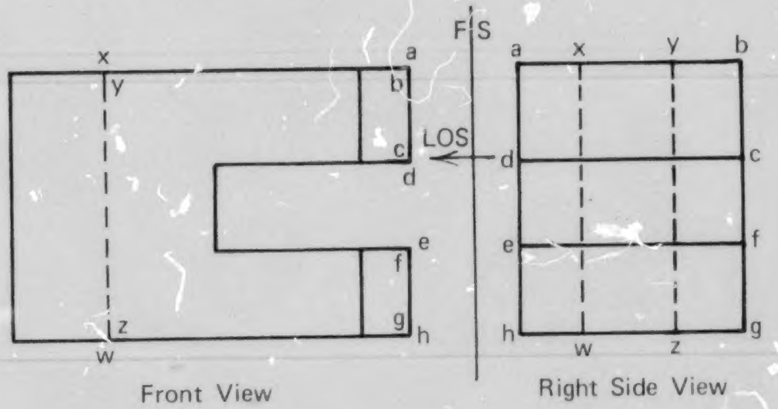
Figure 1

______ a. Point a

______ b. Point z

______ c. Point h

______ d. Point x



Front View

Right Side View

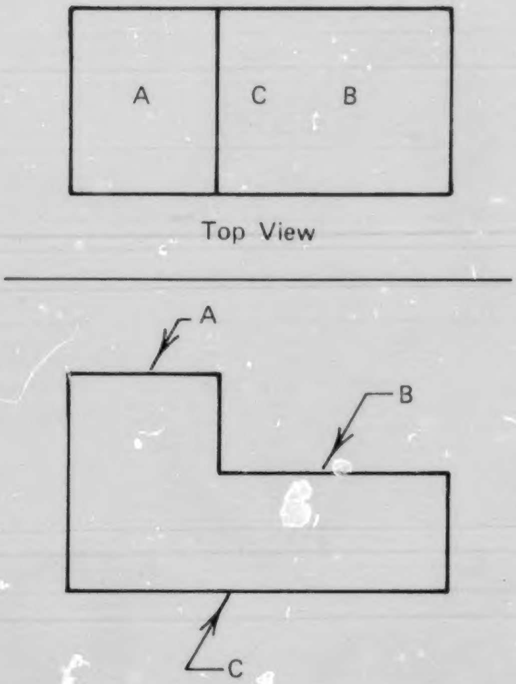
Observer looking on right side view

Figure 2

______ e. Plane A

______ f. Plane B

______ g. Plane C



Top View

Observer looking down
on top view

Front View

3. Arrange in order the steps for constructing an auxiliary view by placing the correct sequence numbers in the appropriate blanks.

______ a. Draw reference or folding line in auxiliary view perpendicular to line of sight at an adequate distance from edge of front view

______ b. Connect points in auxiliary view that are connected in adjacent view; darken lines

______ c. Label points of entire object or certain lines or certain planes where an auxiliary view is needed

______ d. Locate reference or folding line in the adjacent view in either of the following places--back, middle, front, or between views

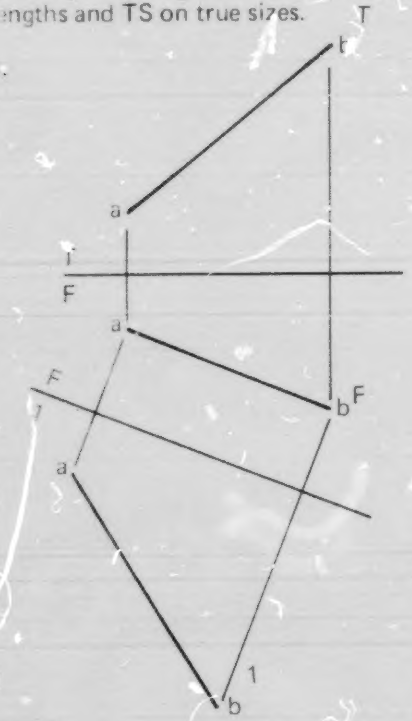
______ e. Draw light projection lines from the points of the view parallel to the line of sight

______ f. Transfer distances from adjacent view in relation to reference plane using dividers

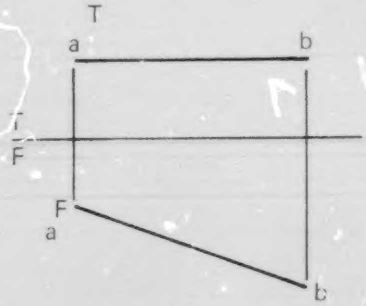
______ g. Select line of sight to get desired view

4. Identify true length lines and true sizes of three view drawings by marking TL on true lengths and TS on true sizes.

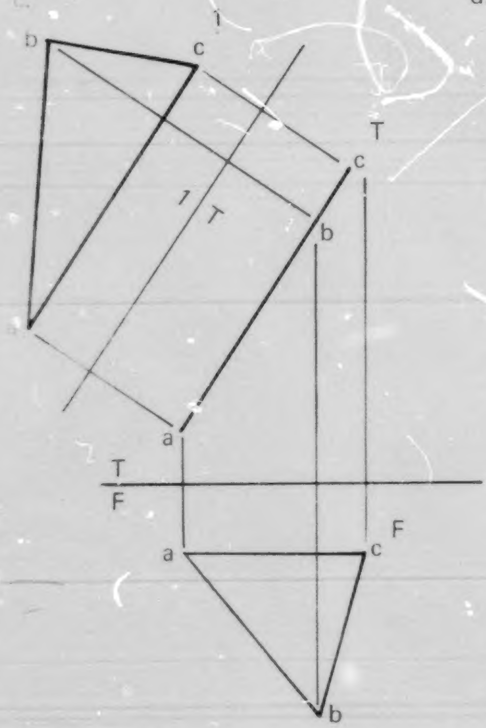
a.


T
b
a
T
F
a
b
F
F
1
a
1
b

b.



c.


1
b
c
T
c
1
T
b
a
a
T
F
a
c
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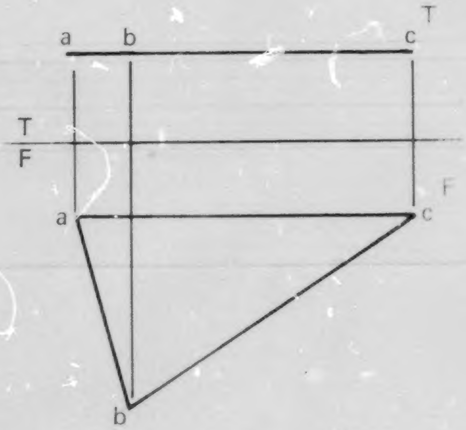
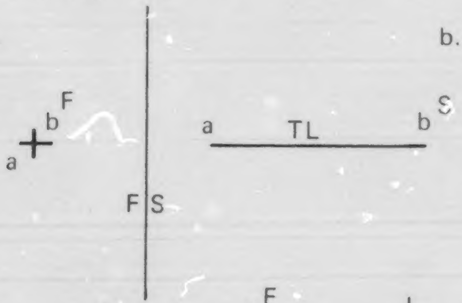
b

d.

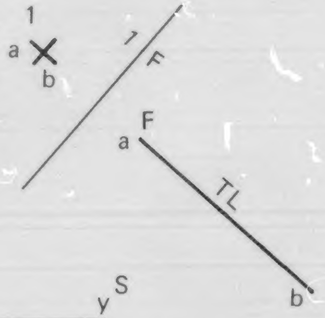

a
b
c
T
T
F
F
a
c
b

5. Identify point views of lines and edge views of planes by marking PV on point view and EV on edge view.

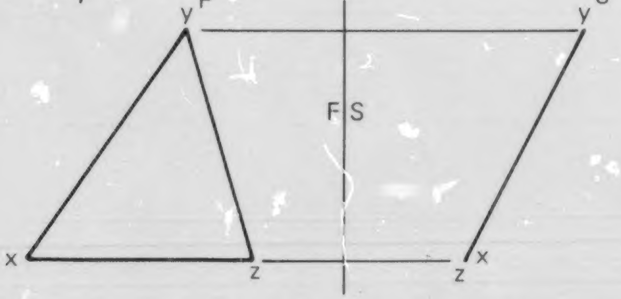
a.



b.



c.



6. Select true statements concerning important characteristics of rotation by placing an "X" in the appropriate blanks.

(NOTE: All parts of a statement must be true before you place an "X" by that statement. If one part is false, the whole statement is considered false.)

_____ a. The path of rotation of any point not on the axis appears as a rectangle in a view showing the axis of rotation as a point

_____ b. The plane of the path of rotation of any point appears in edge view (EV) and perpendicular to the axis in a view showing the axis of rotation in true length

_____ c. In true lengths by rotation,

1) A line may be rotated until it is parallel to a principal plane

2) The line is projected onto the adjacent plane

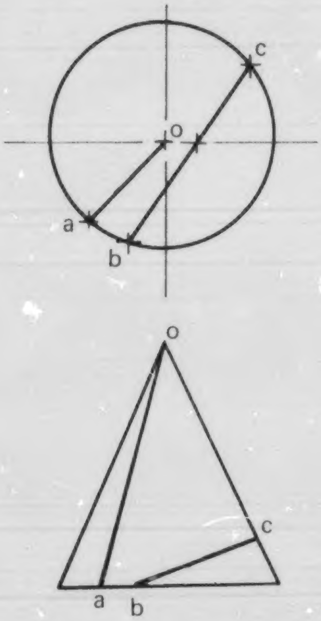
3) Since it is parallel to the folding line, it is in true length in the adjacent plane

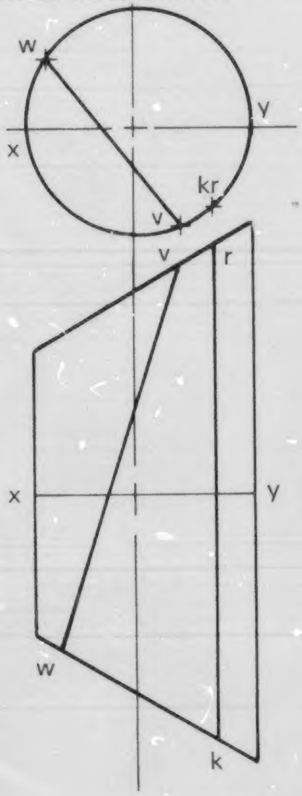
_____ d. In true sizes by rotation,

1) An edge view may be rotated until it is parallel to an orthographic plane

2) The edge view is then projected onto the plane and is foreshortened in size

7. Select elements of single curved surfaces by placing an "X" next to those that are elements.





______ a. oa

______ b. bc

______ c. kr

______ d. xy

______ e. vw

8. List two methods for finding intersections of surfaces.

a. ____

b. ____

9. Name three general groups of developments.

a. ____

b. ____

c. ____

10. Calculate bend allowance when a metal has a thickness of .45", radius of .80", and the number of degrees is 125°. Use the following formula and show all calculations.

$BA = (.017453R + .0078T)\ N$

BA = ____________________

11. Demonstrate the ability to:

    a. Label points, lines, and planes in views.

    b. Identify true lengths and types of lines.

    c. Identify true sizes and types of planes.

    d. Construct true lengths of lines and true sizes of planes using auxiliary views.

    e. Construct true lengths of lines by rotation.

    f. Construct true sizes of planes by rotation.

    g. Locate elements of single curved surfaces.

    h. Construct intersections of surfaces.

    i. Construct intersections of surfaces using two-view method.

    j. Construct radial line developments.

    k. Construct parallel line developments.

    l. Construct special developments using triangulation.

    (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

SHEET METAL DEVELOPMENTS
UNIT X

ANSWERS TO TEST

1.

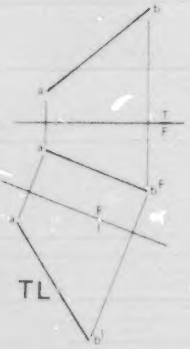
a.	17	h.	25	n.	11	t.	21
b.	10	i.	13	o.	23	u.	8
c.	12	j.	6	p.	15	v.	1
d.	16	k.	19	q.	4	w.	18
e.	2	l.	3	r.	24	x.	9
f.	22	m.	20	s.	7	y.	5
g.	14						

2. a, c, e, f

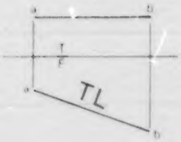
3.

a.	4	e.	5
b.	7	f.	6
c.	1	g.	2
d.	3		

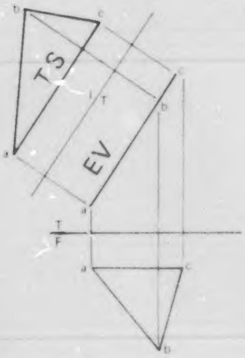
4. a.


b
a
T
F
a
b F
F
1
a
TL
b1

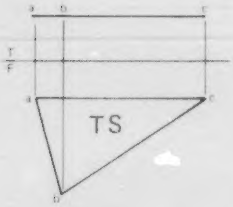
b.



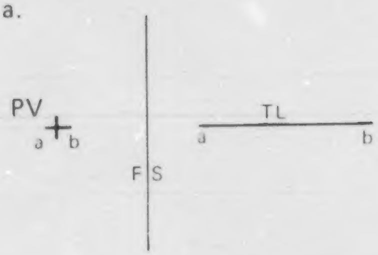
c.


b
c
TS
1
T
c
b
EV
a
a
T
F
a
c
b

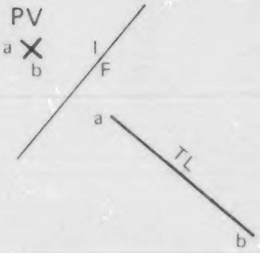
d.


a
b
c
T
F
a
c
TS
b

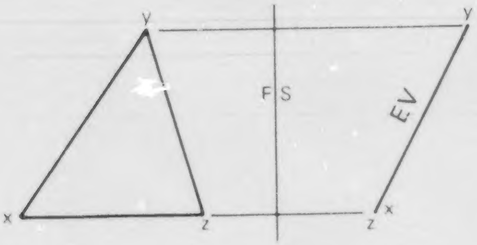
5. a.


PV
a
b
F
S
TL
a
b

b.


PV
a
b
1
F
a
TL
b

c.


y
F
S
y
EV
x
z
z
x

6. b, c

7. a, c

8. Any two of the following:

   a. Edge view given
   b. Auxiliary view method
   c. Cylinders intersecting
   d. Approximate intersections

9. a. Radial line
   b. Parallel line
   c. Triangulation

10. BA = 2.18"

11. Evaluated to the satisfaction of the instructor

POWER TRANSMISSION
UNIT XI

UNIT OBJECTIVE

After completion of this unit, the student should be able to construct various gear and cam drawings. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to power transmission with the correct definitions.
2. Distinguish between advantages of chain drives and gear drives.
3. Distinguish between advantages of chain drives and belt drives.
4. Arrange in order the steps for selecting a V-belt drive.
5. Complete a list of major types of power transmission chains.
6. Match axes positions with the correct types of gears.
7. Identify parts of gear teeth.
8. Identify parts of pinion and gear.
9. Name cutting data needed for spur gear drawings.
10. Identify parts of a bevel gear.
11. Complete a list of cutting data needed for bevel gears.
12. Distinguish between cutting data needed for worm and cutting data needed for worm wheel.
13. Calculate gear ratio.
14. Determine gear rotation.
15. Calculate gear speed.
16. List two types of couplings.
17. Distinguish between types of bearings.
18. Identify cam nomenclature.

19. Identify types of cam followers.

20. Select types of cam motions.

21. Match hydraulic nomenclature with the correct definitions.

22. Match basic pneumatic components with the correct functions.

23. Distinguish between air circuit components.

24. Demonstrate the ability to:

    a. Construct a spur gear drawing.

    b. Construct a bevel gear.

    c. Construct a worm and worm gear.

    d. Calculate gear ratios.

    e. Determine gear rotation.

    f. Calculate gear speeds.

    g. Construct a cam drawing

    h. Select a chain drive.

    i. Select a V-belt drive.

    j. Select types of bearings from handbooks.

POWER TRANSMISSION
UNIT XI

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and assignment sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Set up a display of various power transmission elements.

VII. Allow students to assemble elements where practical.

VIII. Visit and tour a power transmission manufacturing plant. Observe the manufacture of various components such as cams, gears, and chains.

IX. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

   A. Objective sheet

   B. Information sheet

   C. Transparency masters

      1. TM 1--Outside Diameter of Small V-Pulley
      2. TM 2--RPM and Diameter of Driven V-Pulley
      3. TM 3--Belt Length
      4. TM 4--Types of Gears
      5. TM 5--Gear Tooth Terms
      6. TM 6--Parts of Pinion and Gear
      7. TM 7--Working Drawing of a Spur Gear
      8. TM 8--Bevel Gear Nomenclature
      9. TM 9--Working Drawing of Bevel Gear
      10. TM 10--Worm and Worm Gear

    11. TM 11--Working Drawings of Worm and Worm Gear
    12. TM 12--How Gears Change Direction of Rotation
    13. TM 13--A Diagram of Gears Used to Change Speed
    14. TM 14--Cam Nomenclature
    15. TM 15--Types of Cam Followers
    16. TM 16--Uniform Motion
    17. TM 17--Uniform Motion--Cam Profile
    18. TM 18--Modified Motion
    19. TM 19--Parabolic Motion
    20. TM 20--Parabolic Motion--Cam Profile
    21. TM 21--Parabolic Motion--Construction Method
    22. TM 22--Harmonic Motion
    23. TM 23--Harmonic Motion--Cam Profile
    24. TM 24--Combination of Motions
    25. TM 25--Basic Hydraulic and Pneumatic Components

D. Assignment sheets

    1. Assignment Sheet #1--Construct a Spur Gear Drawing
    2. Assignment Sheet #2--Construct a Bevel Gear
    3. Assignment Sheet #3--Construct a Worm and Worm Gear
    4. Assignment Sheet #4--Calculate Gear Ratios
    5. Assignment Sheet #5--Determine Gear Rotation
    6. Assignment Sheet #6--Calculate Gear Speeds
    7. Assignment Sheet #7--Construct a Cam Drawing
    8. Assignment Sheet #8--Select a Chain Drive
    9. Assignment Sheet #9--Select a V-Belt Drive
    10. Assignment Sheet #10--Select Types of Bearings from Handbooks

E. Answers to assignment sheets

F. Test

G. Answers to test

II. References:

A. Jensen, Cecil and Jay Helsel. *Engineering Drawing and Design.* New York, NY: Gregg Division/McGraw-Hill Book Company, 1979.

B. Giesecke, Frederick E., et al. *Technical Drawing.* 12th ed. New York 10022: Macmillan Publishing Co., Inc., 1980.

C. American National Standards Institute. *B6.13-1965 (R1974), B6.1-1978 (R1974), B6.7-1967 (R1974),* and *Y14.7.1 and 2-1971.* New York 10017: American Society of Mechanical Engineers

III. Additional references:

A. Wilson, Charles E. Jr. and Walter J. Michels. *Mechanical Design--Oriented Kinematics.* Chicago 60637: American Technical Society, 1969.

B. Jensen, P.W. *Cam Design and Manufacture.* New York: Industrial Press, 1965.

C. Rothbert, H.A. *Cams.* New York: John Wiley and Sons, 1956.

D. Oberg, Erik, Franklin Jones, and Holbrook Horton. *Machinery's Handbook,* 20th ed. New York: Industrial Pess, Inc., 1979.

E. Dudley, D. W.: *Gear Handbook* , New York: McGraw-Hill Book Co., 1962.

F. *Boston Gear Mechanical Products*, Catalog #M276. Quincey, MA: Boston Gear/Incom International, Inc., 1976.

POWER TRANSMISSION
UNIT XI

INFORMATION SHEET

I. Terms and definitions

   A. Gear drive--Toothed wheel meshing with another toothed wheel

   B. Belt drive--Endless flexible belt on pulleys

   C. Chain drive--Endless chain on sprockets

   D. Couplings--Devices for joining shafts together

   E. Clutches--Devices for stopping or starting a machine without stopping the prime mover

   F. Brakes--Devices for slowing or stopping power driven shafts

   G. Flexible shafts--Devices used to transmit power around corners and different angles when the driver and driven shafts are not lined up

   H. Speed reducer--Any device used to reduce the speed of the output device (driver)

   I. Bearings--Machine parts used to lessen friction

   J. Cams--Machine elements designed to produce a specific motion

   K. Linkages--Motion and function generators

   L. Hydraulics--Liquid is used as power transmission

   M. Pneumatics--Compressed air is used as power transmission

   N. Idler--As a gear it serves to fill up space and reverse direction; as a pulley it serves to take up slack

   O. Countershaft (Jack shaft)--A second motion or intermediate shaft in a power transmission system

   P. Seals--Parts used to protect ball or roller bearings from loss of lubricant and entrance of dust and dirt on bearings

   Q. Bushing--A liner forced in a hole to provide a better wearing or bearing surface and to provide for easy renewal

      (NOTE: Bushings are commonly made from brass or bronze and are sometimes called bearings.)

   R. Power train--Revolving components involved in the transmission of power from the engine to the drive wheel

   S. Gear ratio--The number of revolutions the drive gear must make to turn the driven gear one revolution

INFORMATION SHEET

T. Splines--Multiple keys in the general form of internal and external gear teeth, used to prevent rotation of a shaft

U. Gear reduction--A combination of gears used to reduce the input speed to a lower output speed

II. Advantages of chain drives and gear drives

A. Advantages of chain drive over gear drive

1. Center to center distance is not restricted

2. Easy to install due to greater tolerances

3. Ease of changes in design

4. Better shock absorbing

5. Wear is reduced

6. Faster changing

B. Advantages of gear drive over chain drive

1. When space limitations are important, center to center of gears can be shortest distance

2. Maximum speed ratio can be greater

3. Higher RPM can be obtained

4. Generally more practical at higher RPM and higher horsepower

III. Advantages of chain drives and belt drives

A. Advantages of chain drive over belt drive

1. Does not slip or creep; no power lost

2. Lower loads on bearings due to slack

3. Occupies less overall space

4. Easier to install

5. Better for synchronism for several shafts

6. No static electricity; thus no fire hazard

7. Does not deteriorate with age

8. Operates at higher temperature

9. Slower elongation due to wear

INFORMATION SHEET

B. Advantages of belt drive over chain drive

  1. No lubrication except belt dressing for flexibility
  2. Generally operates with less noise
  3. For extremely long distances, flat belts work well
  4. For extremely high speeds, belts can be used
  5. Less vibration

IV. Steps for selecting a V-belt drive

  A. Decide whether belt will be used on light, normal, or heavy duty equipment

    1. If belt is for light duty, multiply horsepower rating by 1.20; then use normal duty tables

       Example: Light duty equipment include dishwashers, clotheswashers, fans, blowers

    2. If belt is for normal duty, use normal duty tables

       Example: Normal duty equipment include drill presses, power lawn mowers, heating and ventilating fans, generators, buffers

    3. If belt is for heavy duty, multiply horsepower rating by .85; then use normal duty tables

       Example: Heavy duty equipment include metal working machines, compressors, lathes, grinders, industrial machines

  B. Select outside diameter of small V-pulley (Transparency 1)

  C. Select driven V-pulley diameter (Transparency 2)

  D. Determine belt length (Transparency 3)

V. Major types of power transmission chains

  A. Roller
  B. Offset sidebar
  C. Double pitch
  D. Pintle
  E. Detachable
  F. Bead
  G. Inverted tooth

INFORMATION SHEET

VI. Axes positions and types of gears (Transparency 4)

- A. Axes intersect
    - 1. Spiral bevel (miter) gear
    - 2. Plain (straight) bevel gear
    - 3. Hypoid gear
- B. Axes are parallel
    - 1. Spur gear
    - 2. Helical gear
    - 3. Planetary (internal) gear
    - 4. Herringbone gear
- C. Axes do not intersect
    - 1. Worm and worm gear
    - 2. Helical gear
- D. Axes do not intersect and straight line motion converts to circular motion and vice versa--Rack and pinion gear

VII. Parts of gear teeth (Transparency 5)

- A. Face width
- B. Circular pitch
- C. Circular thickness
- D. Dedendum
- E. Addendum
- F. Whole depth
- G. Chordal addendum
- H. Root diameter
- I. Pitch diameter
- J. Outside diameter

INFORMATION SHEET

VIII. Parts of pinion and gear (Transparency 6)

A. Line of action

B. Pressure angle

C. Clearance

D. Working depth

E. Center distance

F. Pitch circle

IX. Cutting data needed for spur gear drawings (Transparency 7)

A. Number of teeth

Formula: Number of teeth = Pitch diameter x Diametral pitch

B. Pitch diameter

Formula: $\text{Pitch diameter} = \frac{\text{Number of teeth}}{\text{Diametral pitch}}$

C. Diametral pitch

Formula: $\text{Diametral pitch} = \frac{\text{Number of teeth}}{\text{Pitch diameter}}$

D. Pressure angle

Formula: Pressure angle = 14 1/2° or 20°

E. Whole depth

Formula: $\text{Whole depth} = \frac{2.157}{\text{Diametral pitch}}$

F. Chordal addendum

Formula: $\text{Chordal addendum} = \text{Addendum} + \frac{(1.57/\text{Diametral pitch})^2}{4\ (\text{Pitch diameter})}$

G. Chordal thickness

Formula: $\text{Chordal thickness} = \text{Pitch diameter}\ \frac{(\text{Sin } 90^\circ)}{\text{No. of teeth}}$

INFORMATION SHEET

X. Parts of a bevel gear (Transparency 8)

   A. Cone distance
   B. Face
   C. Back angle
   D. Pitch diameter
   E. Crown backing
   F. Backing
   G. Mounting distance
   H. Addendum angle
   I. Dedendum angle
   J. Outside DIA
   K. Pitch angle
   L. Root angle
   M. Face angle
   N. Addendum
   O. Whole depth
   P. Dedendum
   Q. Pinion--Smaller of mating gears

   (NOTE: See ANSI *B6.13 - 1965* for more details.)

XI. Cutting data needed for bevel gears (Transparency 9)

   A. Number of teeth in pinion--n
   B. Number of teeth in gear--N
   C. Diametral pitch--P
   D. Pressure angle and form--Basic is 20° = ϕ

   (NOTE: 14 1/2° pressure angle can be used, but certain combinations of teeth must be used to avoid undercutting.)

   E. Addendum for gear = $\frac{\text{1 or select from table}}{\text{Diametral pitch}}$

   (NOTE: Use *Machinery's Handbook* for table.)

INFORMATION SHEET

F. Addendum--for pinion = Working depth x Addendum for gear

G. Addendum--a = $\frac{1}{\text{Diametral pitch}}$

H. Root angle--R = Pitch angle - Dedendum angle

I. Face angle--F = Pitch angle - Addendum angle

J. Whole depth--W = Addendum + Dedendum

(NOTE: This is the same for pinion and gear.)

K. Chordal Addendum for Pinion--C_P = Addendum for Pinion +

$$\frac{\text{Circular thickness for pinion x Cosine of pitch angle of pinion}}{\text{4 x Pitch diameter of pinion}}$$

L. Chordal Addendum for Gear--C_G = Addendum for gear +

$$\frac{\text{Circular thickness for gear - Cosine of pitch angle of pinion}}{\text{4 x Pitch diameter of gear}}$$

M. Chordal Thickness--C_T = Circular thickness of Pinion —

$$\frac{(\text{Circular thickness of Pinion})^3}{6(\text{Pitch diameter of Pinion})^2} - \frac{\text{Select from Table}}{2}$$

(NOTE: Select value from table in *Machinery's Handbook.*)

XII. Cutting data needed for worm and worm wheel (gear) (Transparencies 10 and 11)

A. Cutting data for worm

1. Number of threads--n
2. Pitch--P
3. Pitch diameter--D - (2.4 x Pitch) + 1.1

   (NOTE: This is a recommended value.)
4. Lead and direction--Distance thread moves in one revolution; RH or LH

   (NOTE: In a single thread, lead = pitch; in a double thread, lead = 2 pitch.)
5. Lead angle--Tangent = $\frac{\text{Lead}}{(\text{Pitch diameter})}$
6. Pressure angle--20° or 14 1/2°
7. Whole depth--W = .686 x Pitch

8. Outside diameter--OD = Pitch diameter + .636 x Pitch

9. Face length--F = Pitch $\left(4.5 + \frac{\text{Numbers of teeth on gear}}{50}\right)$

B. Cutting data for worm wheel (gear)

1. Number of teeth--n

2. Pitch--P

3. Pitch diameter--D = Pitch $\left(\frac{\text{number of teeth}}{\pi}\right)$

4. Addendum--a = .3183 x Pitch

5. Whole depth--W = .686 x Pitch

6. Number of threads = t

7. Lead and direction--Distance thread moves in one turn; RH or LH

8. Lead angle--tangent $\lambda = \frac{\text{Lead}}{\pi(\text{Pitch diameter})}$

9. Pressure angle--20° or 14 1/2°

10. Throat diameter--TD = Pitch diameter + .636 x Pitch

11. Outside diameter--OD = Throat diameter + .4775 x Pitch

12. Face radius--R_F = 1/2 Pitch diameter of worm - .318 x Pitch

13. Rim radius--R_r = 1/2 Pitch diameter of worm + Pitch

14. Face width--F = 2.38 x Pitch + .25

15. Center distance--C = 1/2 (Pitch Diameter of wheel + Pitch diameter of worm)

XIII. Calculating gear ratios

A. Count number of teeth on driving gear and teeth on driven gear

B. Divide the number of teeth of the driven gear by the number of teeth of the driving gear

Example: If a driven gear has 60 teeth and a driving gear has 20 teeth, the gear ratio is 60 ÷ 20 = 3, or driving gear turns 3 times to one turn of driven gear.

INFORMATION SHEET

XIV. Determining gear rotation (Transparency 12)

A. Gears are used to change the direction of power transmitted

B. Gear rotation is determined by a driving gear turning in one direction (clockwise) which turns a driven gear in the opposite direction (counterclockwise)

XV. Calculating gear speed (Transparency 13)

A. A small gear will drive a large gear more slowly but with greater torque

B. A large gear will drive a small gear faster but with less torque

C. Formula to find gear speed--R.P.M. x No. of Teeth of driving gear = R.P.M. x No. of Teeth of driven gear

Example: If a gear with 20 teeth revolves at 500 R.P.M. and drives a gear with 40 teeth, how many R.P.M. would the gear with 40 teeth make?

$500(20) = X(40)$

$10{,}000 = 40X$

$250 = X$ Answer is 250 R.P.M.

XVI. Types of couplings

A. Permanent

Example: Flexible, solid, universal, and fluid

B. Clutches

Example: Mechanical, electric, and hydraulic

XVII. Types of bearings

A. Plain bearings

1. Radial
2. Thrust
3. Guide or slipper

B. Antifriction bearings

1. Ball
2. Roller
3. Needle
4. Thrust

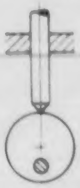
INFORMATION SHEET

XVIII. Cam nomenclature (Transparency 14)

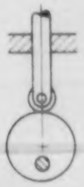
- A. Follower
- B. Base circle
- C. Pressure angle
- D. Trace point
- E. Prime circle
- F. Pitch circle
- G. Direction of motion

XIX. Types of cam followers (Transparency 15)

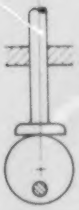
A. Pointed



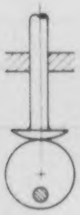
B. Roller



C. Flat face

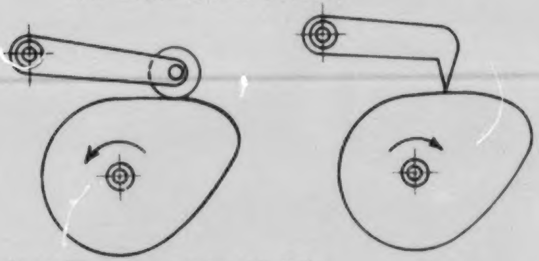


D. Special



INFORMATION SHEET

E. Swinging



XX. Types of cam motions (Transparencies 16-24)

   A. Uniform

   B. Modified

   C. Parabolic

      1. Uniformly accelerated and retarded method

      2. Construction method

   D. Harmonic

   E. Combination

   F. Cycloidal

XXI. Hydraulic nomenclature and definitions (Transparency 25)

   A. Tank--Reservoir to hold fluid

   B. Pump--Device to force liquid through system

   C. Valves--Parts to control flow and pressure

   D. Cylinder or motor--Device to convert fluid energy into mechanical force

   E. Filters and strainers--Parts to clean fluid

   F. Accumulator--A cylinder in which fluid is stored under pressure and used to meet fluctuating demands

   G. Gages--Instruments to measure pressure, temperature, or flow

XXII. Basic pneumatic components and functions (Transparency 25)

   A. Pressure gage--Indicates pressure

   B. Filter--Removes dirt and water

   C. Compressor--Compresses the air

INFORMATION SHEET

D. Receiving tank--Stores compressed air

E. Regulator--Keeps air pressure within an acceptable range

F. Lubricator--Lubricates the operating components of a system

XXIII. Air circuit components

A. Control elements (power valves)

1. 2-way
2. 3-position

B. Power elements

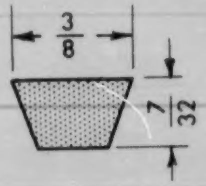
1. Cylinders
2. Air motors

Outside Diameter of Small V-Pulley

HORSEPOWER RATINGS

RPM of small pulley	outside diameter of small v-pulley—inches														
	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00
200	...	...	...	...	...	...	...	...	...	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
400	...	...	0.06	0.08	0.12	0.15	0.18	0.22	0.25	0.31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
600	0.04	0.07	0.08	0.12	0.18	0.22	0.27	0.32	0.36	[illegible]	0.51	[illegible]	[illegible]	[illegible]	[illegible]
800	0.05	0.08	0.11	0.15	0.22	0.28	0.34	0.41	0.45	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1000	0.06	0.10	0.12	0.18	0.26	0.33	0.42	0.48	0.55	0.64	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1160	0.07	0.11	0.15	0.21	0.29	0.38	0.46	0.54	0.62	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1400	0.08	0.12	0.17	0.23	0.33	0.43	0.53	0.64	0.74	0.84	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1600	0.08	0.14	0.19	0.25	0.36	0.48	0.58	0.69	0.80	0.90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1750	0.08	0.15	0.20	0.25	0.38	0.51	0.63	0.74	0.85	0.96	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2000	0.09	0.16	[illegible]	0.28	0.41	0.55	0.68	0.81	0.92	1.05	1.17	[illegible]	[illegible]	[illegible]	[illegible]
2200	0.09	0.17	0.24	0.31	0.44	0.58	0.72	0.86	0.99	1.12	1.25	[illegible]	[illegible]	[illegible]	[illegible]
2400	0.10	0.18	0.25	0.32	0.45	0.61	0.76	0.91	1.05	1.19	1.32	[illegible]	[illegible]	[illegible]	[illegible]
2600	0.10	0.19	0.26	0.35	0.47	0.64	0.79	0.96	1.09	1.24	1.38	[illegible]	[illegible]	[illegible]	[illegible]
2800	0.11	0.19	0.28	0.36	0.48	0.66	0.83	0.99	1.14	1.28	1.42	[illegible]	[illegible]	[illegible]	[illegible]
3000	0.11	0.21	0.29	0.39	0.49	0.68	0.85	1.02	1.18	1.32	1.46	[illegible]	[illegible]	[illegible]	[illegible]
3200	0.11	0.21	0.30	0.39	0.51	0.70	0.88	1.05	1.20	1.36	1.50	1.50	[illegible]	[illegible]	[illegible]
3450	0.12	0.22	0.32	0.41	0.51	0.71	0.90	1.07	1.23	1.38	1.52	1.52	[illegible]	[illegible]	[illegible]
3600	0.12	0.22	0.33	0.42	0.52	0.72	0.91	1.09	1.25	1.40	1.54	1.54	[illegible]	[illegible]	[illegible]
3800	0.12	0.22	0.33	0.42	0.52	0.72	0.92	1.09	1.25	1.41	1.54	1.54	1.54	[illegible]	[illegible]
4000	0.12	0.22	0.34	0.44	0.53	0.72	0.92	1.10	1.26	1.40	1.52	1.52	1.52	1.52	[illegible]

For ░ Background use a



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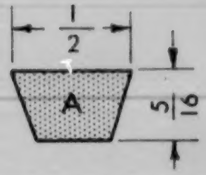
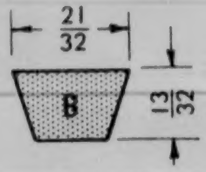


For ■ Background use a



NOTE: This table incorporates a service factor of 1.3. For heavy duty, multiply normal duty horsepower rating by .85. For light duty, multiply normal duty horsepower rating by 1.20.

Courtesy of T. B. Wood's Sons Company

RPM and Diameter of Driven V-Pulley

DRIVEN SPEEDS FOR 1160 RPM MOTORS

DriveN V-Pulley O.D. inches	DriveR V-Pulley O.D.—inches												
	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50
1.5	1160	1392	1625	1855	2085	2325	2550	2785	3015	3250	3480	3715	...
2.0	829	995	1160	1325	1490	1658	1825	1988	2150	2315	2485	2650	
2.5	645	774	903	1031	1160	1290	1418	1546	1675	1805	1933	2032	2190
3.0	528	634	739	845	950	1057	1160	1266	1370	1475	1580	1685	1793
3.5	447	536	625	715	804	894	982	1071	1160	1248	1340	1428	1518
4.0	387	465	542	620	696	775	851	929	1008	1082	1160	1238	1315
4.5	341	409	477	545	614	682	750	819	886	955	1022	1091	1160
5.0	305	366	427	488	549	610	671	732	794	854	915	976	1039
5.5	277	332	381	442	497	553	608	663	718	774	829	884	939
6.0	253	302	353	404	454	505	555	605	655	706	756	806	857
7.0	215	258	301	344	388	430	474	516	560	602	648	688	732
8.0	187	224	262	297	337	374	411	449	486	524	561	599	636
10.0	149	179	208	238	268	298	328	357	387	417	446	477	506
12.0	123	148	173	197	222	247	272	296	321	346	370	395	420

DRIVEN SPEEDS FOR 1750 RPM MOTORS

DriveN V-Pulley O.D. inches	DriveR V-Pulley O.D.—inches												
	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50
1.5	1750	2100	2450	2800	3150	3500	3850	...	...	...	...	...	...
2.0	1250	1500	1750	2000	2250	2500	2750	3000	3250	3500	3750	4000	
2.5	974	1167	1360	1555	1750	1945	2140	2330	2530	2725	2915	3110	3305
3.0	797	955	1113	1272	1431	1590	1750	1910	2070	2225	2385	2545	2700
3.5	674	808	942	1077	1210	1346	1480	1615	1750	1885	2020	2155	2290
4.0	584	700	817	935	1050	1168	1283	1400	1518	1634	1750	1865	1985
4.5	516	618	720	824	926	1030	1131	1235	1339	1440	1543	1650	1750
5.0	462	554	646	737	830	922	1013	1105	1198	1290	1382	1473	1568
5.5	417	500	584	667	750	834	917	1000	1082	1167	1250	1333	1417
6.0	381	456	533	610	685	760	837	913	990	1065	1140	1217	1290
6.5	350	420	490	560	630	700	771	840	910	980	1050	1120	1190
7.0	324	389	454	518	584	648	713	778	843	907	973	1039	1102
8.0	282	339	394	451	507	564	620	676	734	789	845	902	959
9.0	250	300	350	400	450	500	550	600	650	700	750	800	850
10.0	224	270	315	360	405	450	495	540	585	630	675	720	765
11.0	203	244	285	326	366	407	448	488	530	570	610	652	692
12.0	186	224	261	298	336	373	410	446	485	522	560	596	634

DRIVEN SPEEDS FOR 3500 RPM MOTORS

DriveN V-Pulley O.D. inches	DriveR V-Pulley O.D.—inches												
	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50
1.5	3500	4200	4900	5600	6300	7000	7700						
2.0	2500	3000	3500	4000	4500	5000	5500	6000	6500	7000	7500	8000	
2.5	1948	2334	2720	3110	3500	3890	4280	4660	5060	5450	5830	6220	6610
3.0	1594	1910	2236	2544	2862	3180	3500	3820	4140	4450	4770	5090	5400
3.5	1348	1616	1884	2154	2420	2692	2960	3230	3500	3770	4040	4310	4580
4.0	1168	1400	1634	1870	2030	2336	2566	2800	3036	3268	3500	3730	3970
4.5	1032	1236	1440	1648	1852	2060	2262	2470	2678	2880	3086	3300	3500
5.0	924	1108	1292	1474	1660	1844	2026	2210	2396	2580	2764	2946	3136
5.5	834	1000	1168	1334	1500	1668	1834	2000	2164	2334	2500	2666	2834
6.0	762	912	1066	1220	1370	1520	1774	1826	1980	2130	2280	2434	2580
6.5	700	840	980	1120	1260	1400	1542	1680	1820	1960	2100	2240	2380
7.0	648	778	908	1036	1168	1296	1426	1556	1686	1814	1946	2078	2204
8.0	564	678	788	902	1014	1128	1240	1352	1468	1578	1690	1804	1918
9.0	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1750
10.0	448	540	630	720	810	900	990	1080	1170	1260	1350	1440	1530
11.0	406	488	570	652	732	814	896	976	1060	1140	1220	1304	1384
12.0	372	448	522	596	672	746	820	892	970	1044	1120	1192	1268

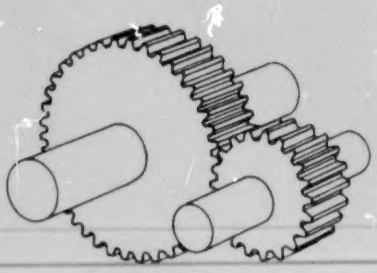
Courtesy of T. B. Wood's Sons Company

Belt Length

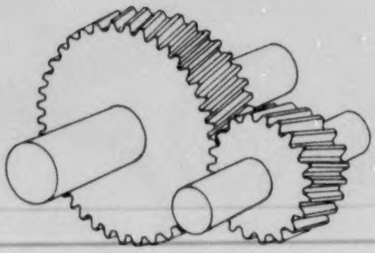
Installation allowance	take-up	belt length	sum of both v-belt pulley diameters																								
			4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12	12½	13	13½	14	14½	15	15½	16
½	½	16	4.9	4.5	**4.1**																						
⅝	½	18	5.9	5.5	5.1	**4.6**																					
⅝	½	20	6.9	6.5	6.1	5.6	**5.2**																				
⅝	½	22	7.9	7.5	7.1	6.6	6.2	**5.8**																			
⅝	½	24	8.9	8.5	8.1	7.6	7.2	6.8	**6.3**	**5.8**																	
⅝	½	26	9.9	9.5	9.1	8.6	8.2	7.8	7.3	**6.9**	**6.5**																
⅝	½	28	10.9	10.5	10.1	9.6	9.2	8.8	8.4	7.9	**7.6**	**7.1**	**6.6**														
⅝	½	30	11.9	11.5	11.1	10.6	10.2	9.8	9.4	8.9	8.6	**8.1**	**7.7**	**7.3**													
⅝	½	32	12.9	12.5	12.1	11.6	11.2	10.8	10.4	10.0	9.6	9.1	**8.7**	**8.4**	**8.0**												
⅝	½	34	13.9	13.5	13.1	12.7	12.2	11.8	11.4	11.0	10.6	10.2	9.7	9.4	**9.0**	**8.6**											
⅝	½	36	14.9	14.5	14.1	13.7	13.2	12.8	12.4	12.0	11.6	11.2	10.7	10.4	10.0	**9.6**	**9.0**										
⅝	½	38	15.9	15.5	15.1	14.7	14.2	13.8	13.4	13.0	12.6	12.2	11.8	11.4	11.0	10.6	**10.0**	**9.7**	**9.1**								
¾	½	40	16.9	16.5	16.1	15.7	15.3	14.8	14.4	14.0	13.6	13.2	12.8	12.4	12.0	11.6	11.1	**10.7**	**10.1**	**9.8**							
¾	½	42	17.9	17.5	17.1	16.7	16.3	15.8	15.4	15.0	14.6	14.2	13.8	13.4	13.1	12.6	12.1	11.7	**11.2**	**10.8**	**10.2**						
¾	½	44	18.9	18.5	18.1	17.7	17.3	16.8	16.4	16.0	15.6	15.2	14.8	14.4	14.1	13.6	13.1	12.8	12.2	**11.9**	**11.2**	**10.9**					
¾	½	46	19.9	19.5	19.1	18.7	18.3	17.9	17.4	17.0	16.6	16.2	15.8	15.4	15.1	14.6	14.1	13.8	13.2	12.9	**12.3**	**12.0**	**10.9**	**10.5**			
¾	½	48	20.9	20.5	20.1	19.7	19.3	18.9	18.4	18.0	17.7	17.2	16.8	16.4	16.1	15.6	15.1	14.8	14.3	13.9	13.3	**13.0**	**12.0**	**11.6**	**11.3**		
¾	½	50	21.9	21.5	21.1	20.7	20.3	19.9	19.4	19.0	18.7	18.2	17.8	17.4	17.1	16.7	16.2	15.8	15.3	14.9	14.4	14.0	**13.1**	**12.7**	**12.4**	**12.1**	**11.7**
¾	½	52	22.9	22.5	22.1	21.7	21.3	20.9	20.4	20.0	19.7	19.2	18.8	18.4	18.1	17.7	17.2	16.8	16.3	15.9	15.4	15.0	14.1	**13.8**	**13.5**	**13.1**	**12.8**
¾	½	54	23.9	23.5	23.1	22.7	22.3	21.9	21.4	21.0	20.7	20.2	19.8	19.4	19.1	18.7	18.2	17.8	17.3	17.0	16.4	16.1	15.2	14.8	**14.5**	**14.2**	**13.8**
¾	½	56	24.9	24.5	24.1	23.7	23.3	22.9	22.4	22.0	21.7	21.2	20.8	20.4	20.1	19.7	19.2	18.8	18.3	18.0	17.4	17.1	16.2	15.9	15.6	**15.2**	**14.9**
¾	½	58	25.9	25.5	25.1	24.7	24.3	23.9	23.4	23.0	22.7	22.2	21.8	21.4	21.1	20.7	20.2	19.8	19.3	19.0	18.5	18.1	17.3	16.9	16.6	16.3	15.9
⅞	¾	60	26.9	26.5	26.1	25.7	25.3	24.9	24.5	24.0	23.7	23.2	22.8	22.4	22.1	21.7	21.2	20.8	20.4	20.0	19.5	19.1	18.3	18.0	17.6	17.3	17.0
⅞	¾	62	27.9	27.5	27.1	26.7	26.3	25.9	25.5	25.0	24.7	24.3	23.8	23.4	23.1	22.7	22.2	21.8	21.4	21.0	20.5	20.1	19.4	19.0	18.7	18.3	18.0
⅞	¾	64	28.9	28.5	28.1	27.7	27.3	26.9	26.5	26.0	25.7	25.3	24.8	24.4	24.1	23.7	23.2	22.9	22.4	22.0	21.5	21.1	20.4	20.0	19.7	19.4	19.0
⅞	¾	66	29.9	29.5	29.1	28.7	28.3	27.9	27.5	27.0	26.7	26.3	25.9	25.4	25.1	24.7	24.2	23.9	23.4	23.0	22.5	22.2	21.4	21.1	20.7	20.4	20.0
⅞	¾	68	30.9	30.5	30.1	29.7	29.3	28.9	28.5	28.1	27.7	27.3	26.9	26.4	26.1	25.7	25.2	24.9	24.4	24.0	23.5	23.2	22.4	22.1	21.7	21.4	21.0
⅞	¾	70	31.9	31.5	31.1	30.7	30.3	29.9	29.5	29.1	28.7	28.3	27.9	27.4	27.1	26.7	26.2	25.9	25.4	25.0	24.5	24.2	23.5	23.1	22.8	22.4	22.1
⅞	¾	72	32.9	32.5	32.1	31.7	31.3	30.9	30.5	30.1	29.7	29.3	28.9	28.4	28.1	27.7	27.2	26.9	26.4	26.0	25.5	25.2	24.5	24.1	23.8	23.4	23.1
⅞	¾	74	33.9	33.5	33.1	32.7	32.3	31.9	31.5	31.1	30.7	30.3	29.9	29.4	29.1	28.7	28.2	27.9	27.4	27.0	26.5	26.2	25.5	25.1	24.8	24.4	24.1
⅞	¾	76	34.9	34.5	34.1	33.7	33.3	32.9	32.5	32.1	31.7	31.3	30.9	30.4	30.1	29.7	29.2	28.9	28.4	28.0	27.6	27.2	26.5	26.2	25.8	25.5	25.1
⅞	¾	78	35.9	35.5	35.1	34.7	34.2	33.9	33.5	33.1	32.7	32.3	31.9	31.4	31.1	30.7	30.2	29.9	29.4	29.0	28.6	28.2	27.5	27.2	26.8	26.5	26.1
⅞	¾	80	36.9	36.5	36.1	35.7	35.3	34.9	34.5	34.1	33.7	33.3	32.9	32.4	32.1	31.7	31.3	30.9	30.4	30.0	29.6	29.2	28.6	28.2	27.9	27.5	27.1
⅞	¾	82	37.6	37.1	36.7	36.3	35.9	35.5	35.1	34.7	34.3	33.9	33.5	33.0	32.7	32.3	31.9	31.5	31.0	30.7	30.2	29.8	29.2	28.8	28.5	28.1	27.8
⅞	¾	84	38.9	38.5	38.1	37.7	37.3	36.9	36.5	36.1	35.7	35.3	34.9	34.4	34.1	33.7	33.3	32.9	32.4	32.1	31.6	31.2	30.6	30.2	29.9	29.5	29.2

Courtesy of T. B. Wood's Sons Company

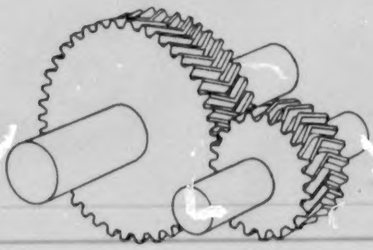
Types of Gears



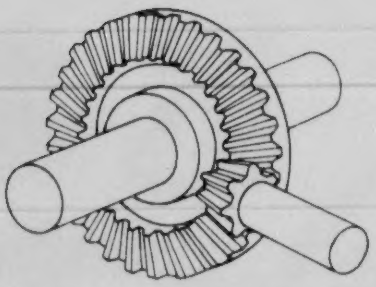
Straight Spur



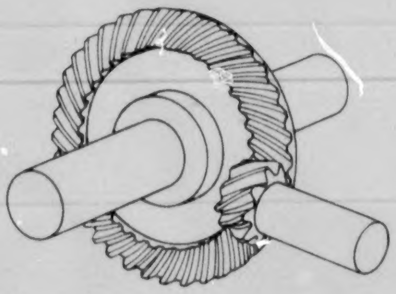
Helical Spur



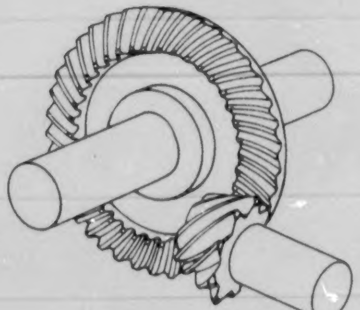
Herringbone



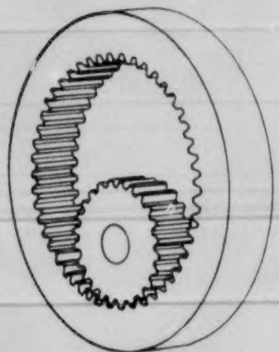
Plain Bevel



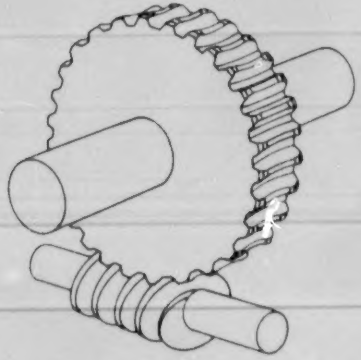
Spiral Bevel



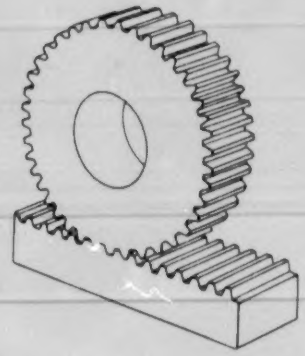
Hypoid



Planetary



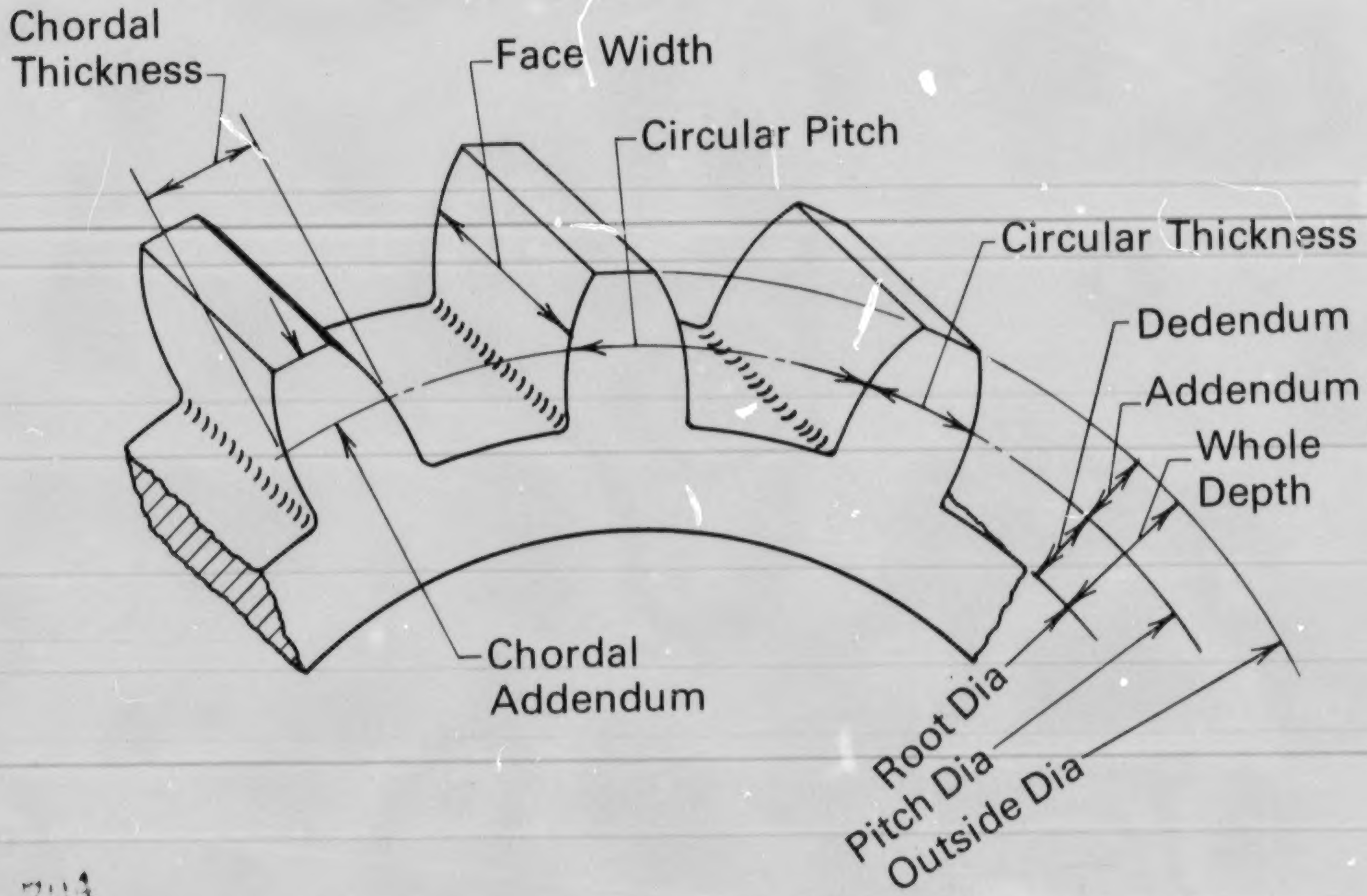
Worm



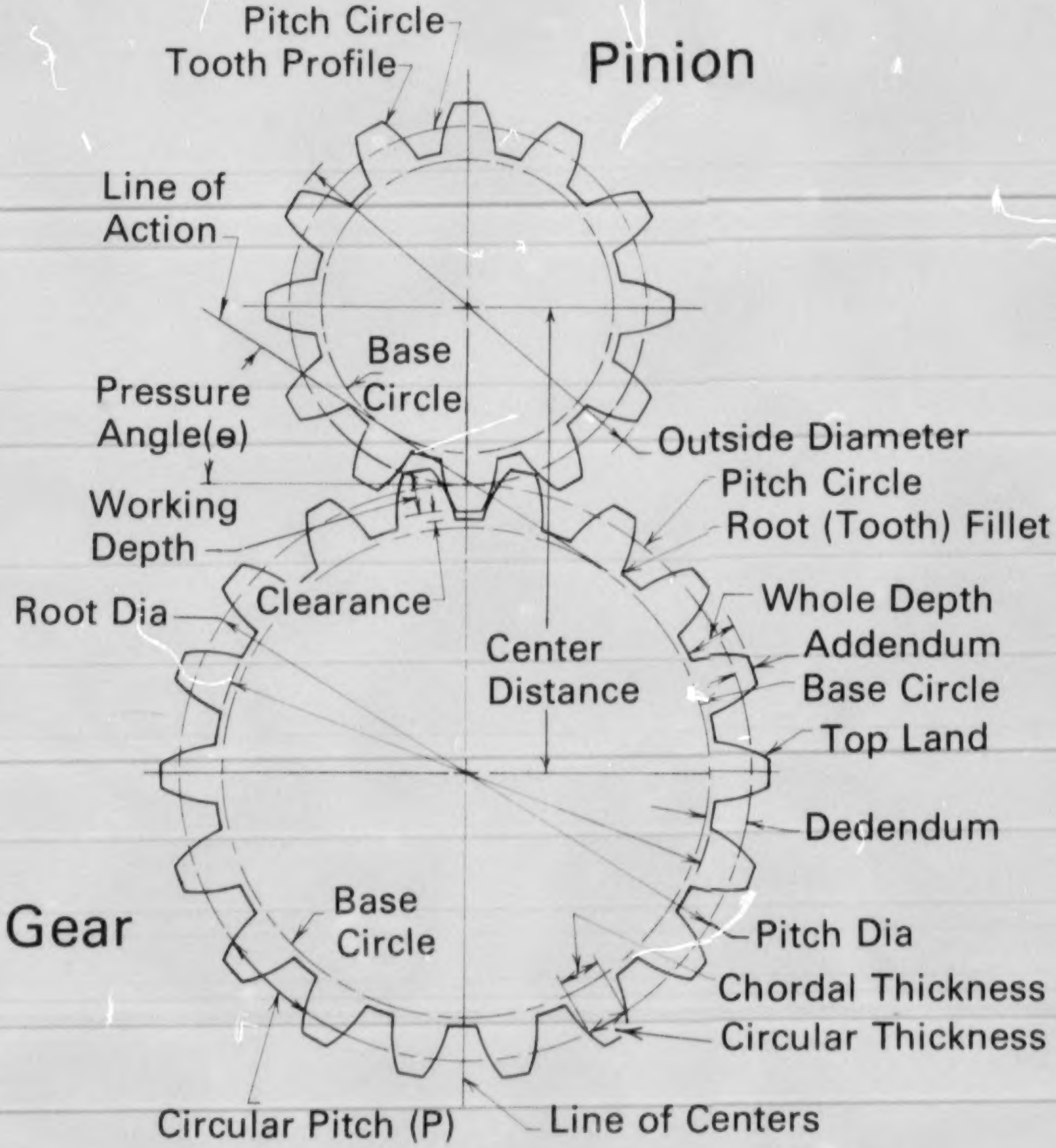
Rack and Pinion

Courtesy of Deere & Company, Moline, IL

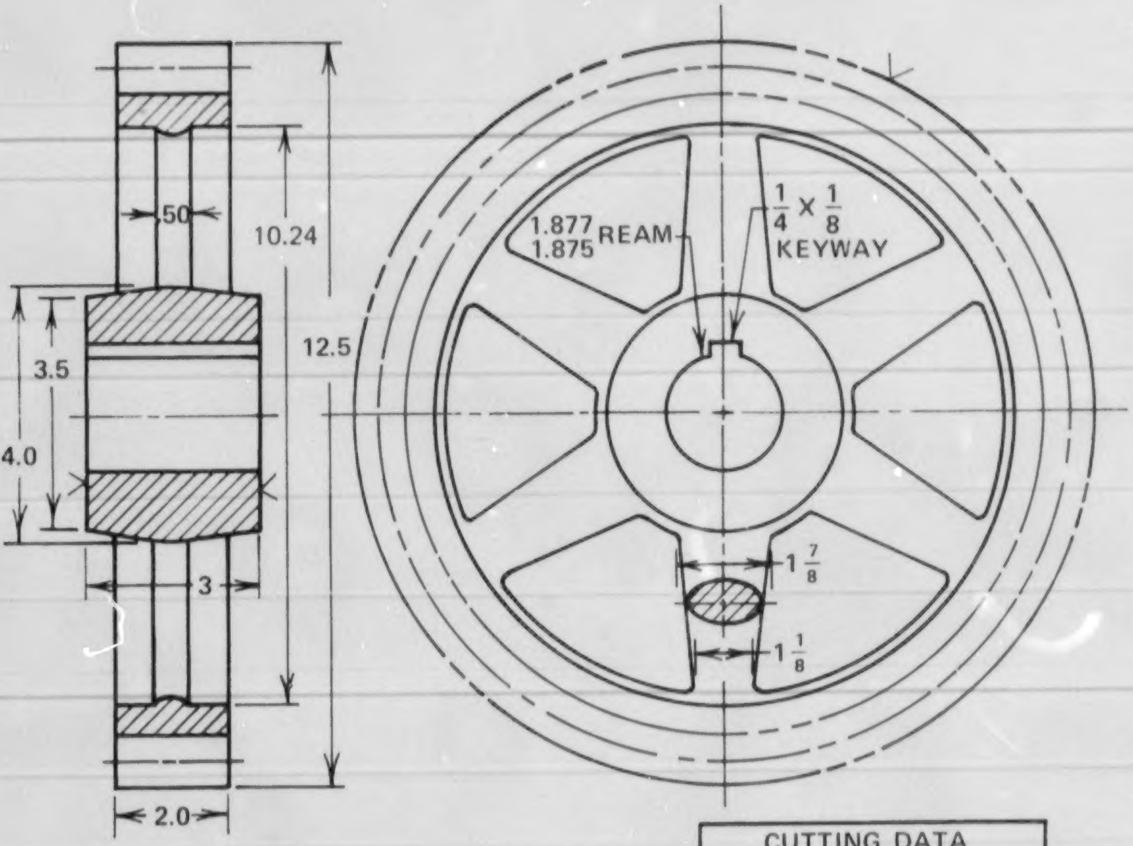
Gear Tooth Terms


Chordal Thickness
Face Width
Circular Pitch
Circular Thickness
Dedendum
Addendum
Whole Depth
Chordal Addendum
Root Dia
Pitch Dia
Outside Dia

Parts of Pinion and Gear


Pitch Circle
Tooth Profile
Pinion
Line of Action
Base Circle
Pressure Angle(θ)
Working Depth
Outside Diameter
Pitch Circle
Root (Tooth) Fillet
Root Dia
Clearance
Whole Depth
Addendum
Center Distance
Base Circle
Top Land
Dedendum
Gear
Base Circle
Pitch Dia
Chordal Thickness
Circular Thickness
Circular Pitch (P)
Line of Centers

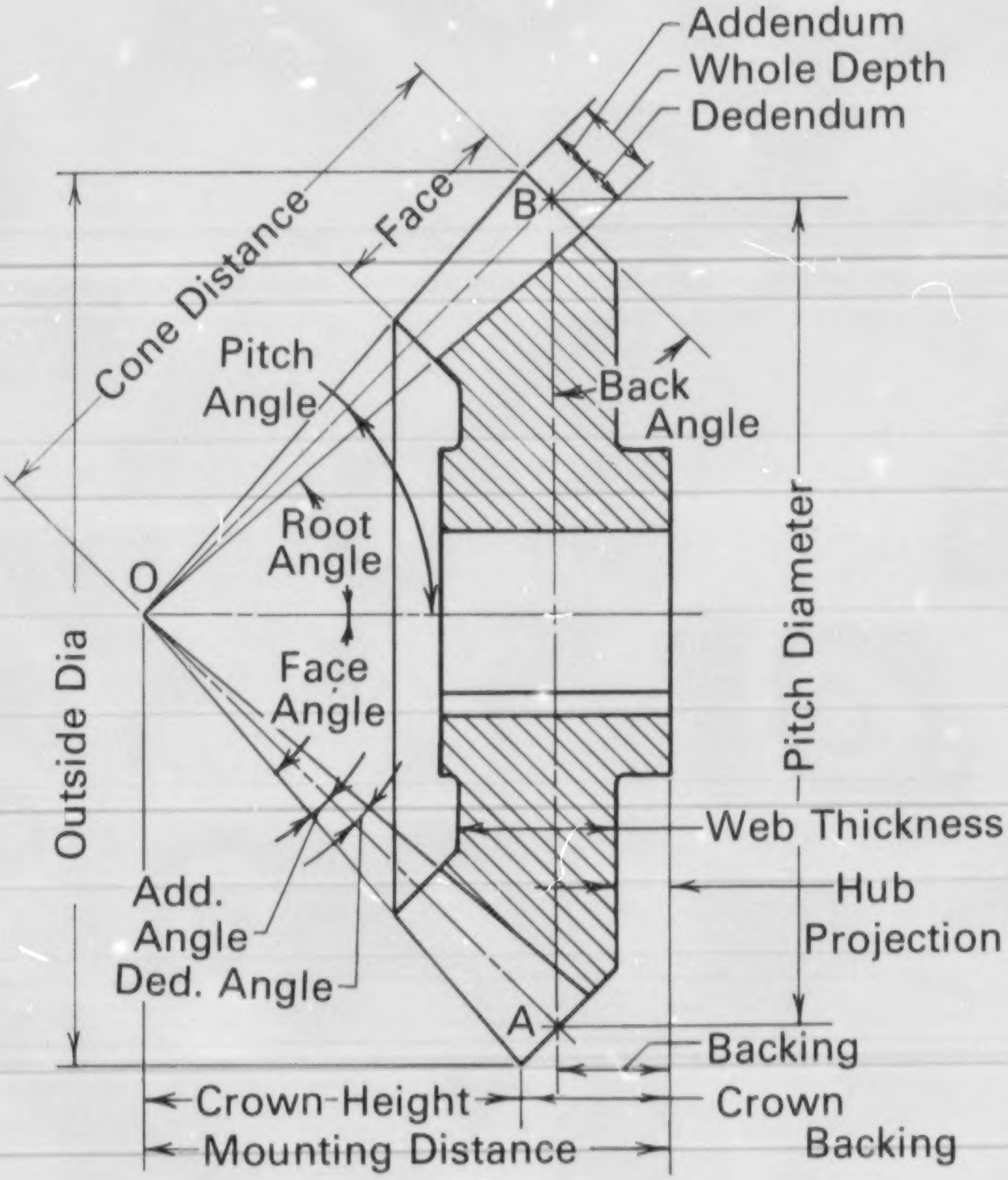
Working Drawing of a Spur Gear


.50
10.24
12.5
3.5
4.0
3
2.0
1.877
1.875 REAM
$\frac{1}{4} \times \frac{1}{8}$
KEYWAY
$1\frac{7}{8}$
$1\frac{1}{8}$

ROUNDS AND FILLETS $\frac{1}{8}$ R

CUTTING DATA	
NO. OF TEETH	48
PITCH DIAMETER	12.00
DIA PITCH	4.00
PRESSURE ANGLE	14½°
WHOLE DEPTH	.5395
CHORDAL ADD	.25
CHORDAL THICK	.3927
WORKING DEPTH	.5000
CIRCULAR THICK	.3927

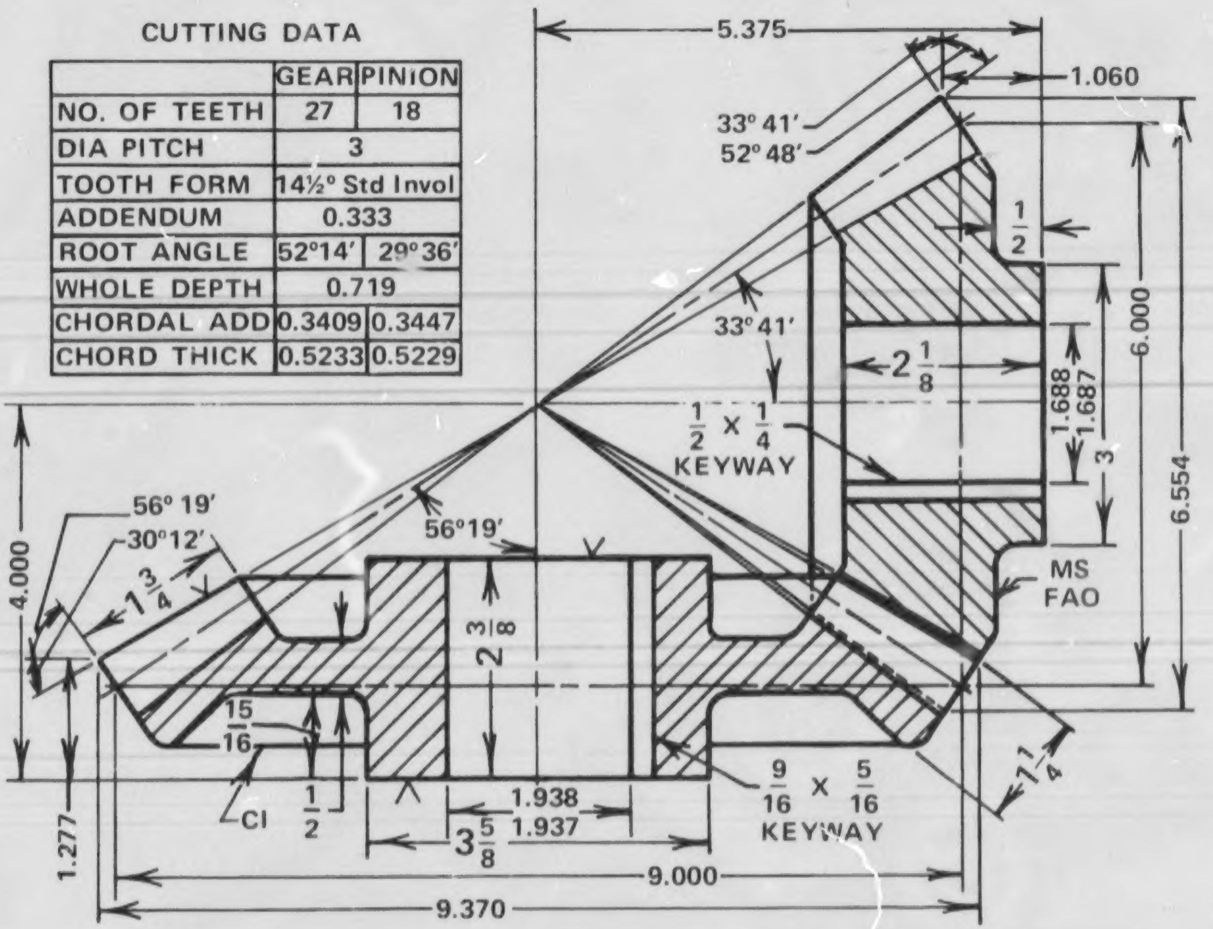
Bevel Gear Nomenclature


Addendum
Whole Depth
Dedendum
Cone Distance
Face
B
Pitch Angle
Back Angle
Root Angle
O
Face Angle
Outside Dia
Pitch Diameter
Web Thickness
Hub Projection
Add. Angle
Ded. Angle
A
Backing
Crown-Height
Crown Backing
Mounting Distance

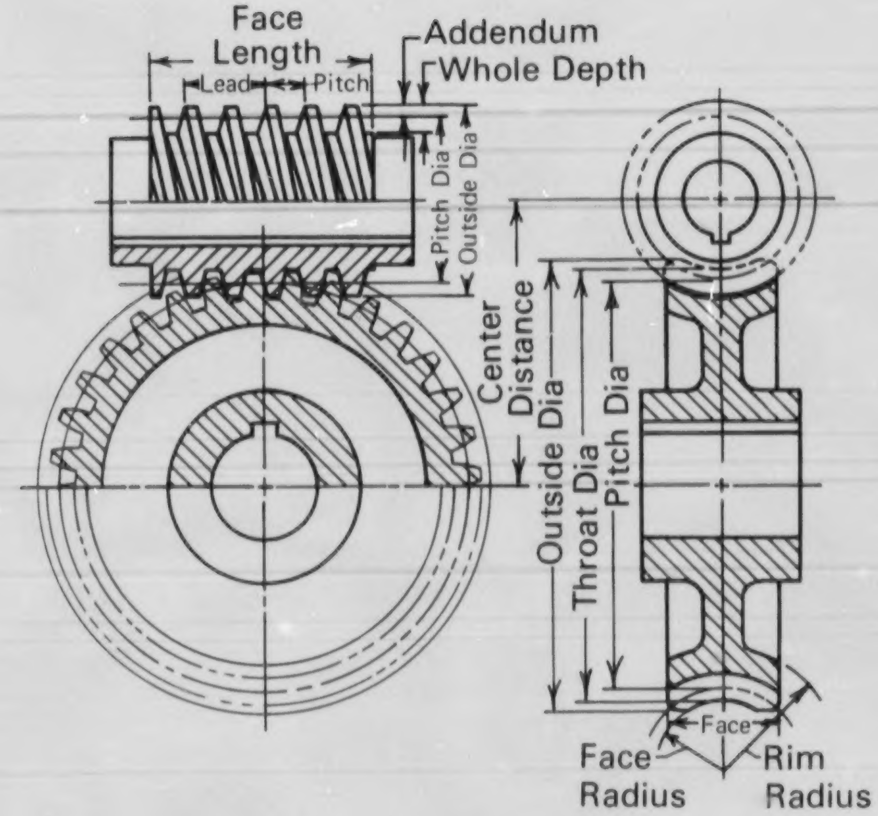
Working Drawing of Bevel Gear

CUTTING DATA

	GEAR	PINION
NO. OF TEETH	27	18
DIA PITCH	3	
TOOTH FORM	14½° Std Invol	
ADDENDUM	0.333	
ROOT ANGLE	52°14′	29°36′
WHOLE DEPTH	0.719	
CHORDAL ADD	0.3409	0.3447
CHORD THICK	0.5233	0.5229


5.375
1.060
33° 41′
52° 48′
1/2
33° 41′
2 1/8
6.000
1.688
1.687
3
6.554
1/2 X 1/4
KEYWAY
MS
FAO
56° 19′
30°12′
1 3/4
4.000
56°19′
2 3/8
15/16
CI
1/2
1.277
1.938
1.937
3 5/8
9/16 X 5/16
KEYWAY
1 1/4
9.000
9.370

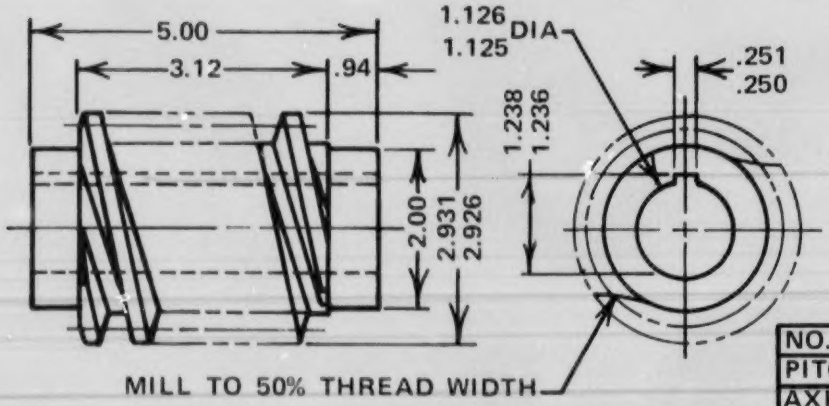
Worm and Worm Gear


Face Length
Lead
Pitch
Addendum
Whole Depth
Pitch Dia
Outside Dia
Center Distance
Outside Dia
Throat Dia
Pitch Dia
Face
Face Radius
Rim Radius

711

Working Drawings of Worm and Worm Gear

Worm

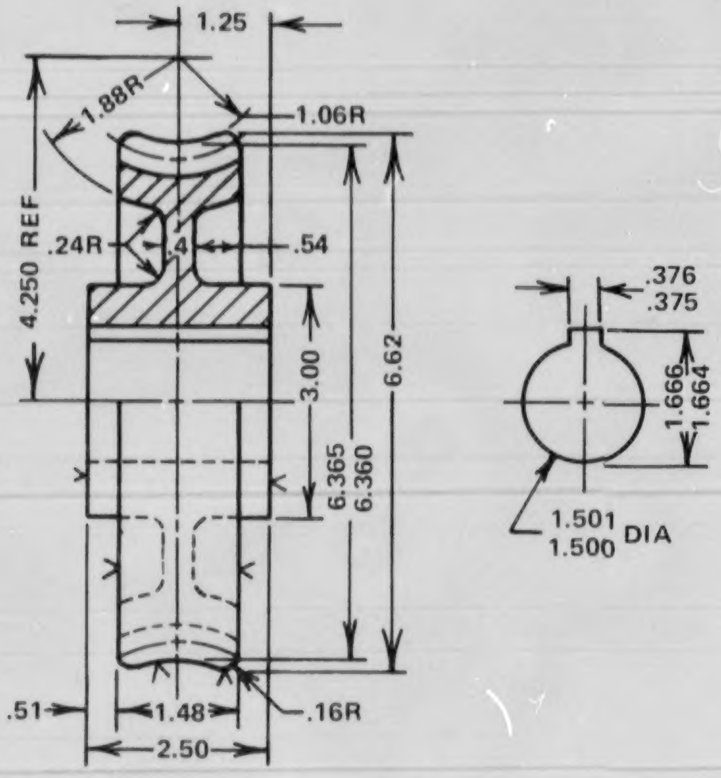

5.00
3.12
.94
1.126
1.125 DIA
.251
.250
1.238
1.236
2.00
2.931
2.926
MILL TO 50% THREAD WIDTH

FAO - GRIND THREAD FLANKS

CUTTING DATA

NO. OF THREADS	2
PITCH DIA	2.533
AXIAL PITCH	0.625
LEAD - RH	1.250
LEAD ANGLE	8°56′
PRESSURE ANGLE	14½°
WHOLE DEPTH	0.429

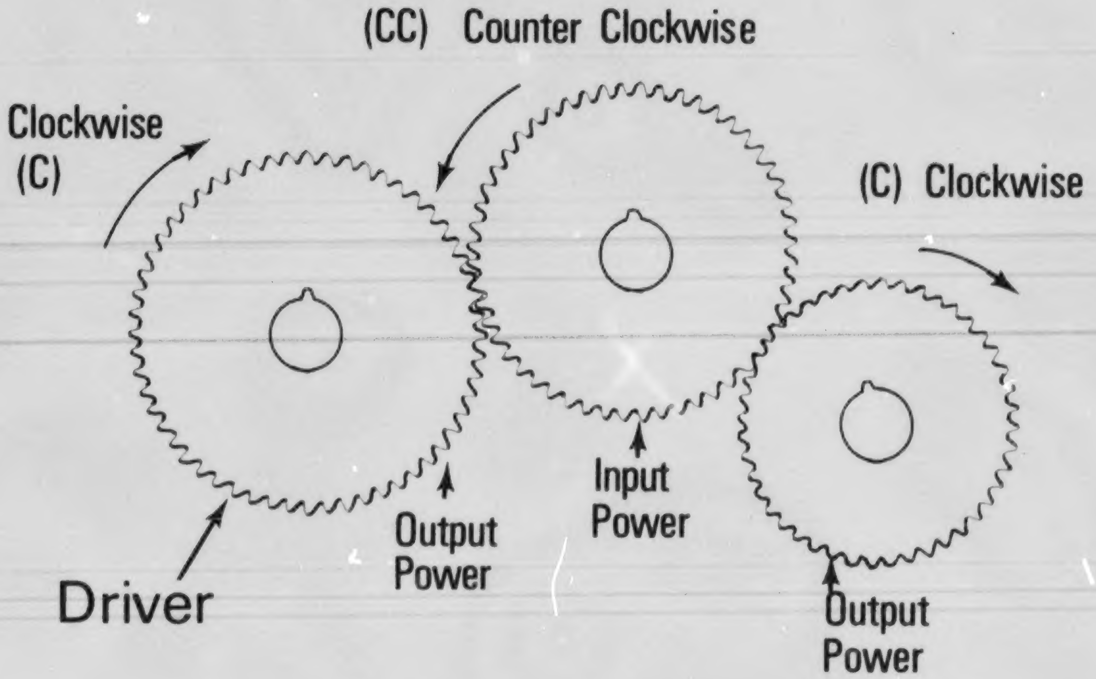
Worm Gear

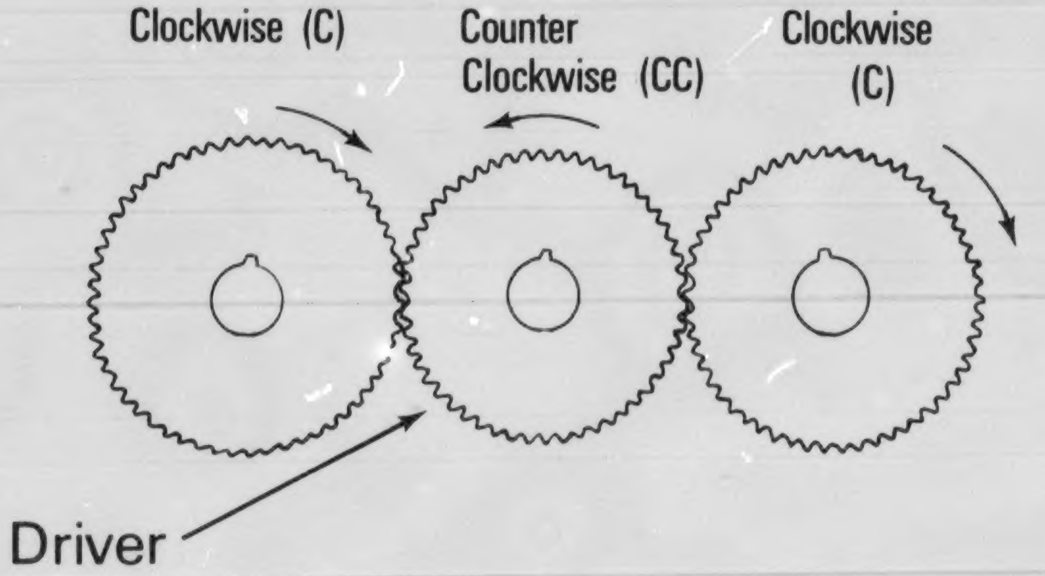

1.25
1.88R
1.06R
4.250 REF
.24R
.4
.54
3.00
6.62
6.365
6.360
.51
1.48
.16R
2.50
.376
.375
1.666
1.664
1.501
1.500 DIA

CUTTING DATA

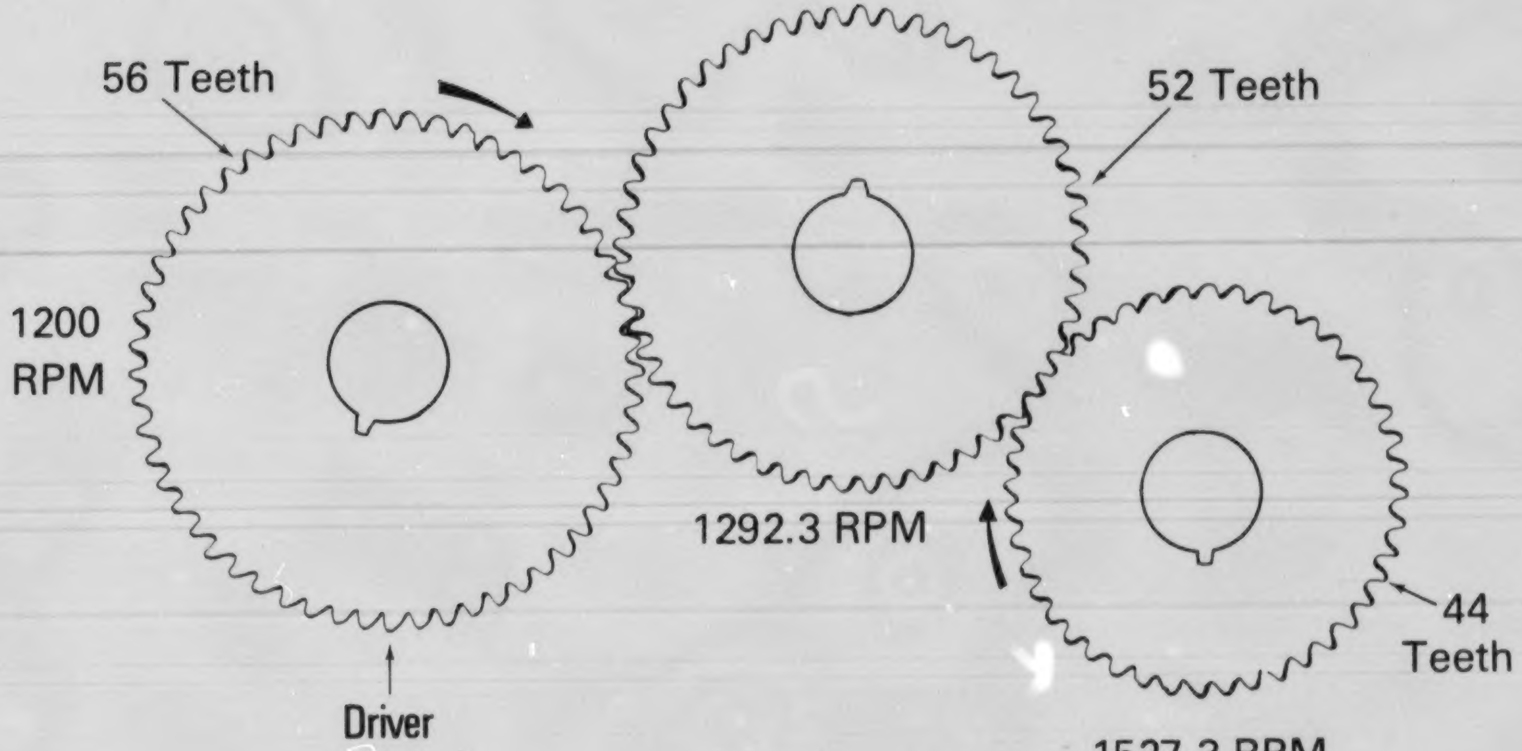
NO. OF TEETH	30
PITCH DIA	5.967
ADDENDUM	0.199
WHOLE DEPTH	0.429
NO. of THREADS	2
AXIAL PITCH	0.625
LEAD - RH	1.250
LEAD ANGLE	8° 56′
PRESS. ANGLE	14½°

How Gears Change Direction of Rotation

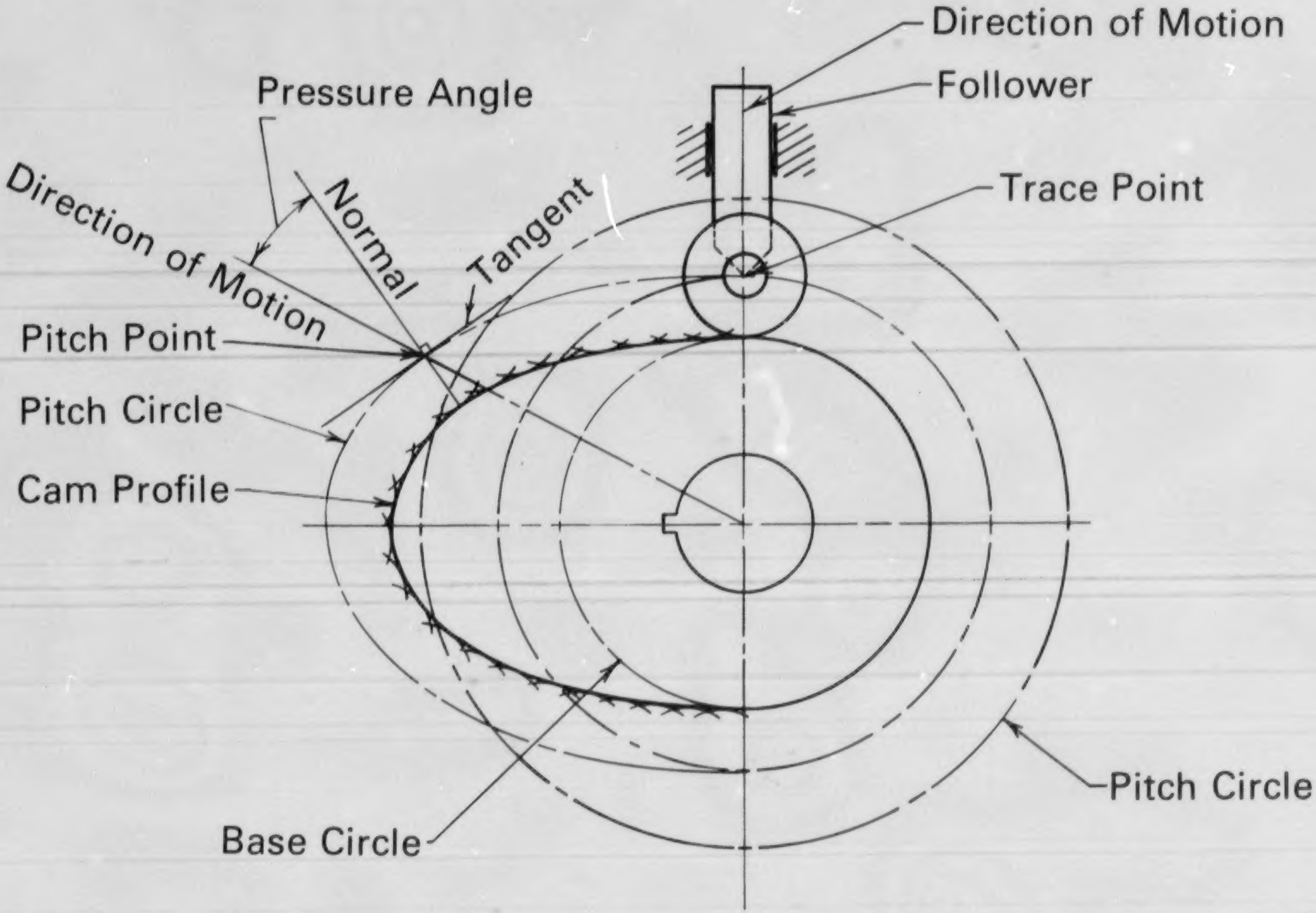

(CC) Counter Clockwise
Clockwise (C)
(C) Clockwise
Output Power
Input Power
Driver
Output Power


Clockwise (C)
Counter Clockwise (CC)
Clockwise (C)
Driver

A Diagram of Gears Used to Change Speed


56 Teeth
1200
RPM
Driver
52 Teeth
1292.3 RPM
44
Teeth
1527.3 RPM

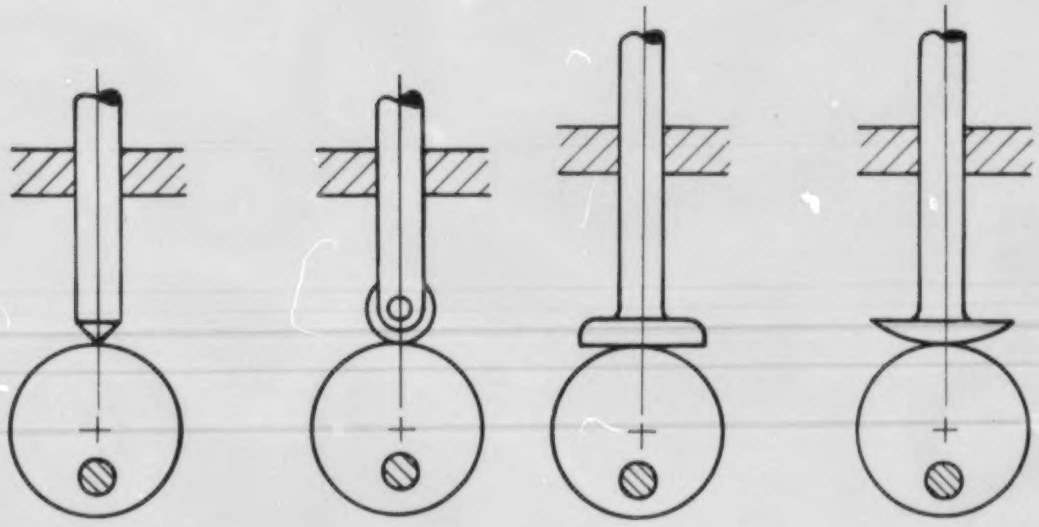
Cam Nomenclature

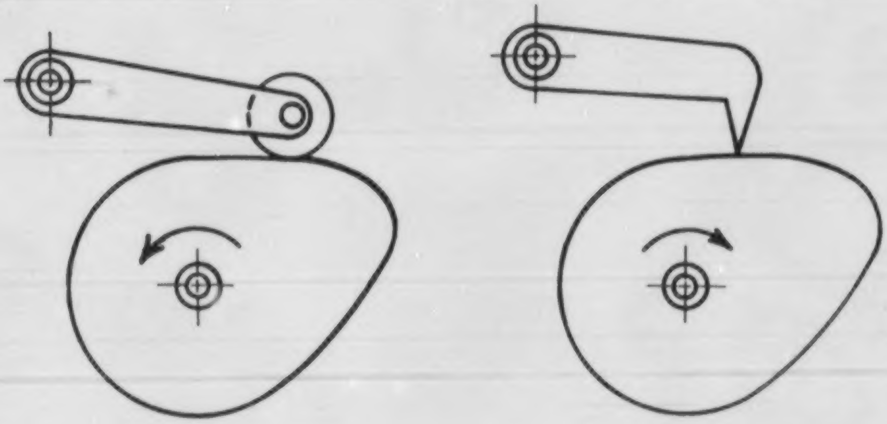

Direction of Motion
Follower
Pressure Angle
Direction of Motion
Normal
Tangent
Trace Point
Pitch Point
Pitch Circle
Cam Profile
Pitch Circle
Base Circle

TM 14

MD - 895

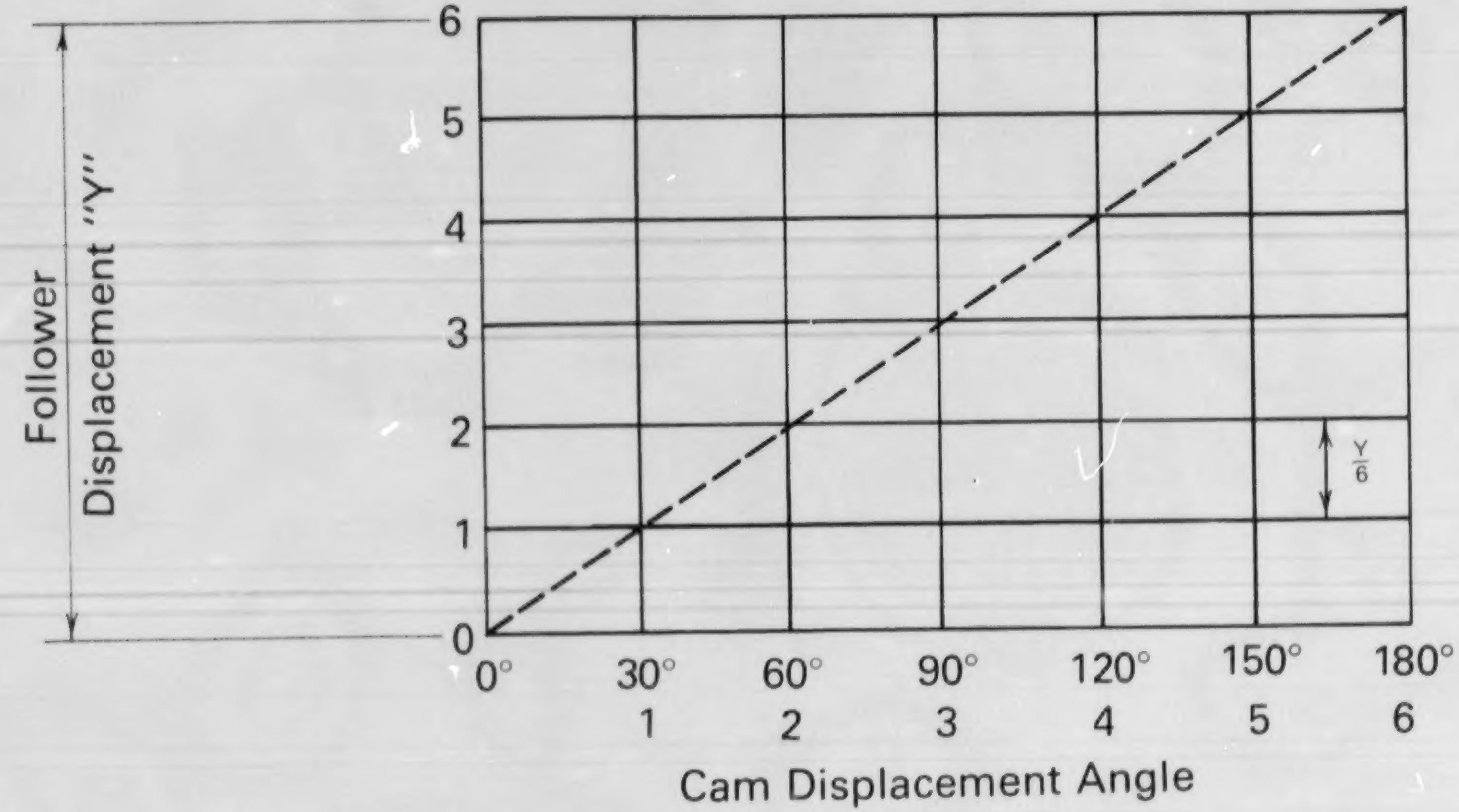
Types of Cam Followers


Pointed
Roller
Flat Face
Special

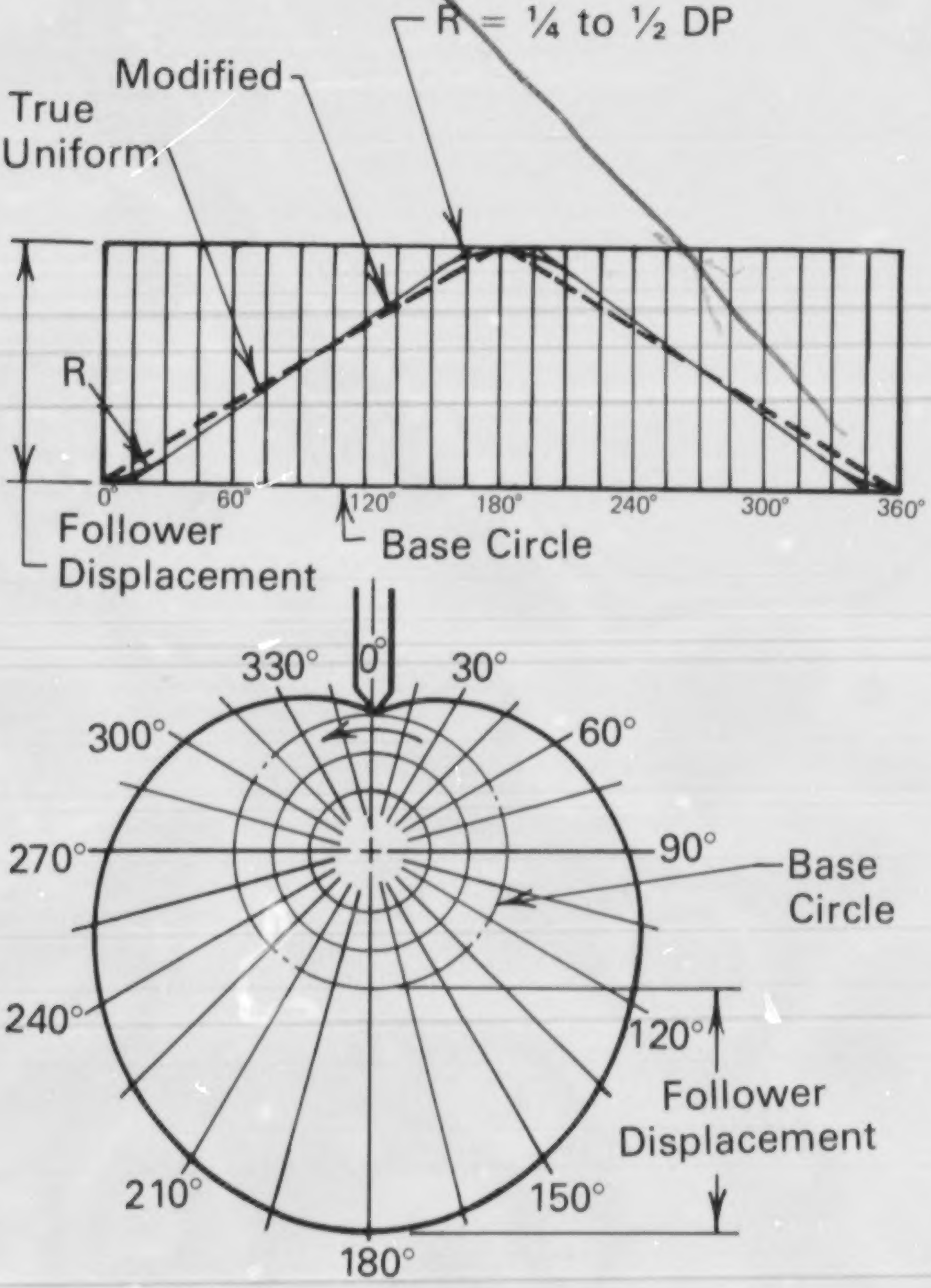


Cams with Swinging Followers

Uniform Motion

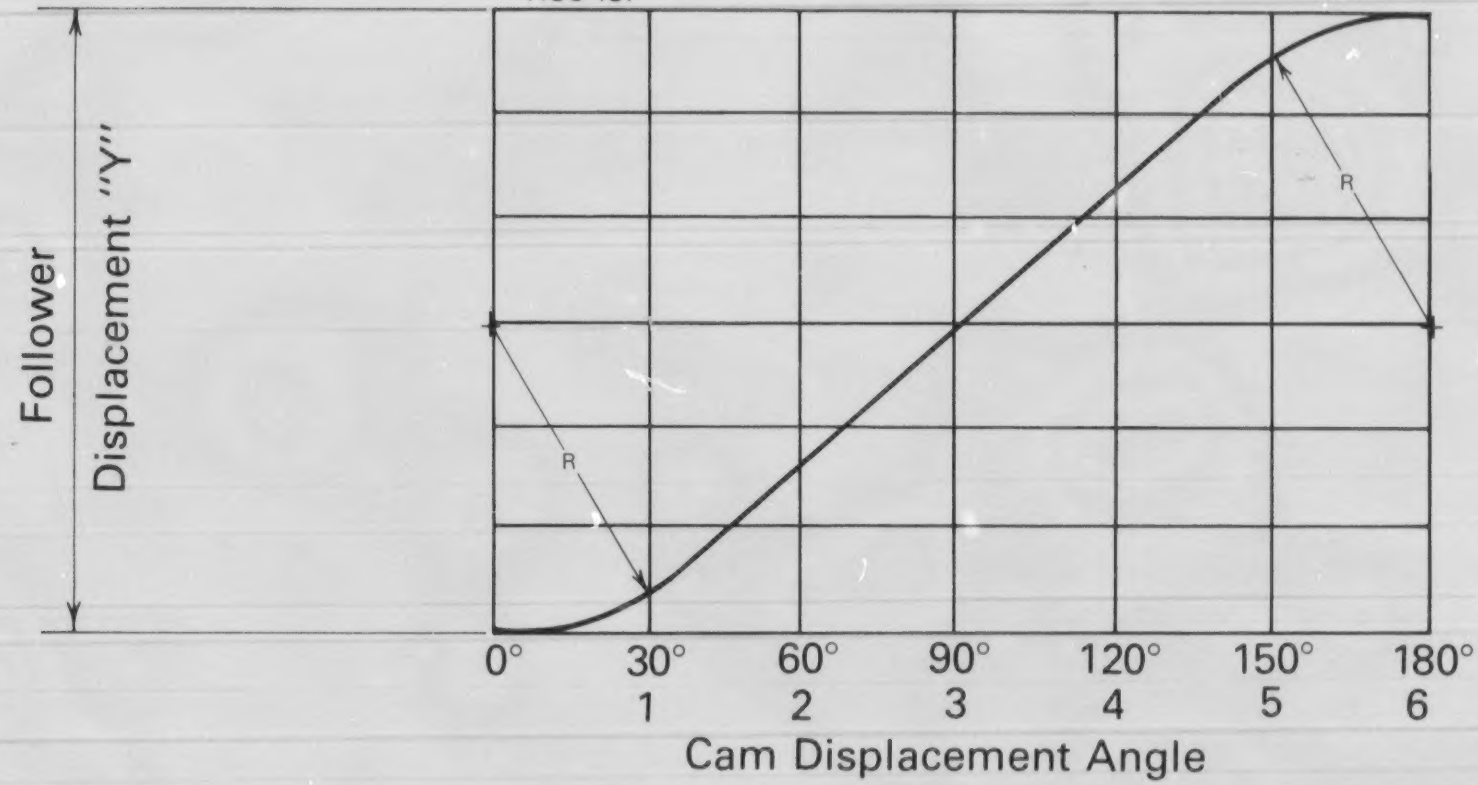


Uniform Motion - Cam Profile


R = ¼ to ½ DP
Modified
True Uniform
R
0°
60°
120°
180°
240°
300°
360°
Follower Displacement
Base Circle
330°
0°
30°
300°
60°
270°
90°
Base Circle
240°
120°
Follower Displacement
210°
150°
180°

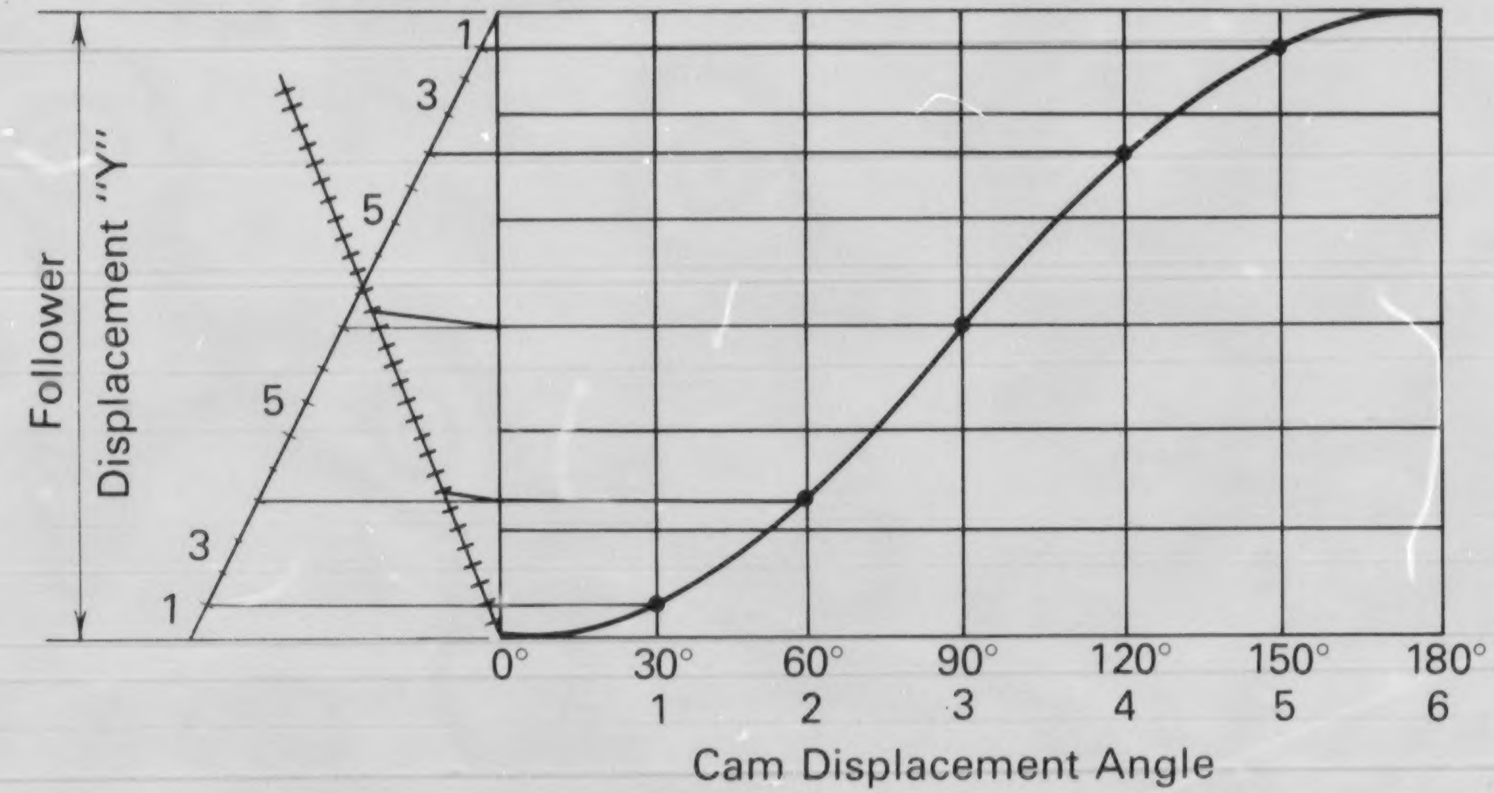
Modified Motion

NOTE: Radius (R) varies between 1/3 to full rise depending upon how sharp the rise is.

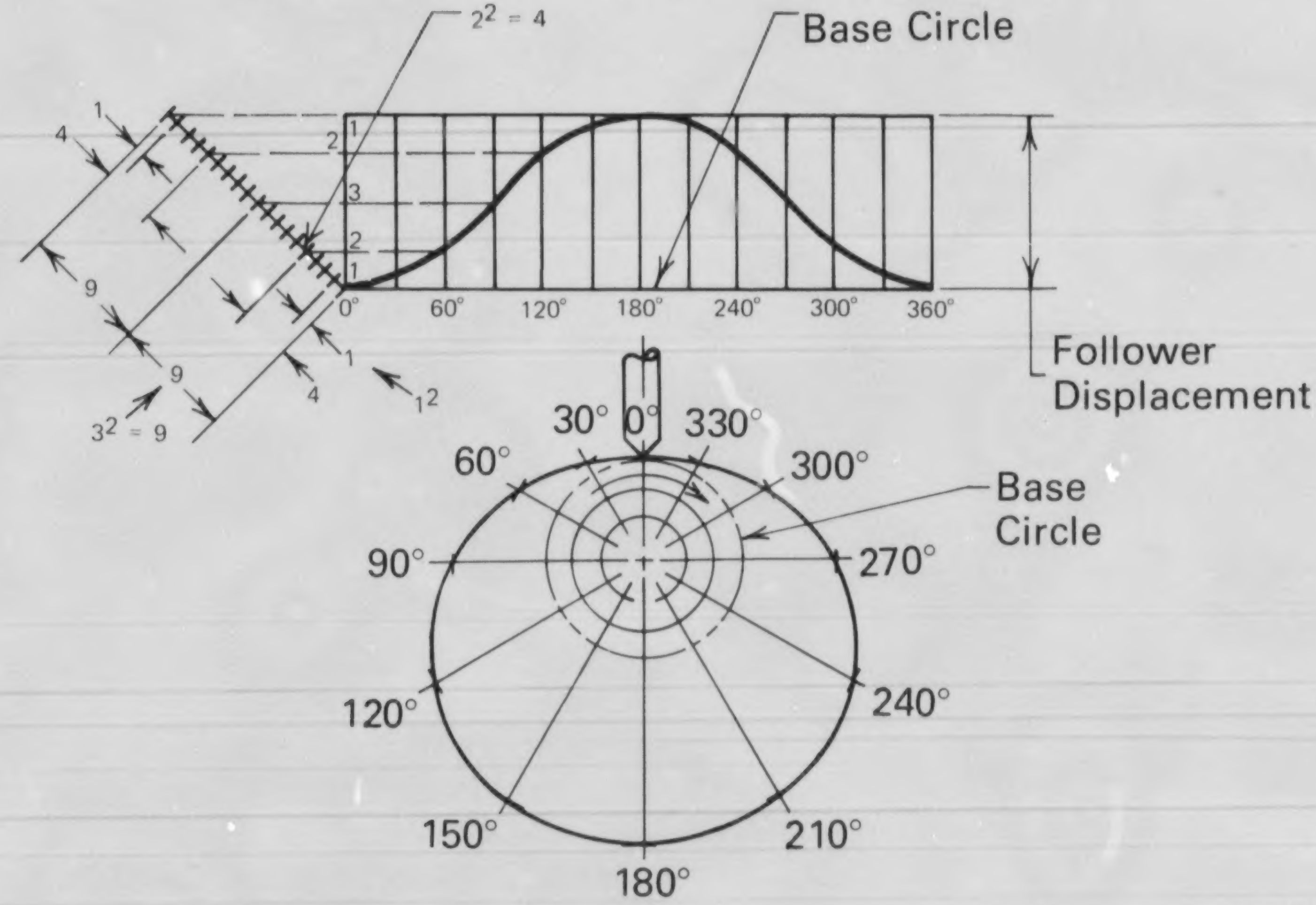


Parabolic Motion

Uniformly Accelerated & Retarded Method

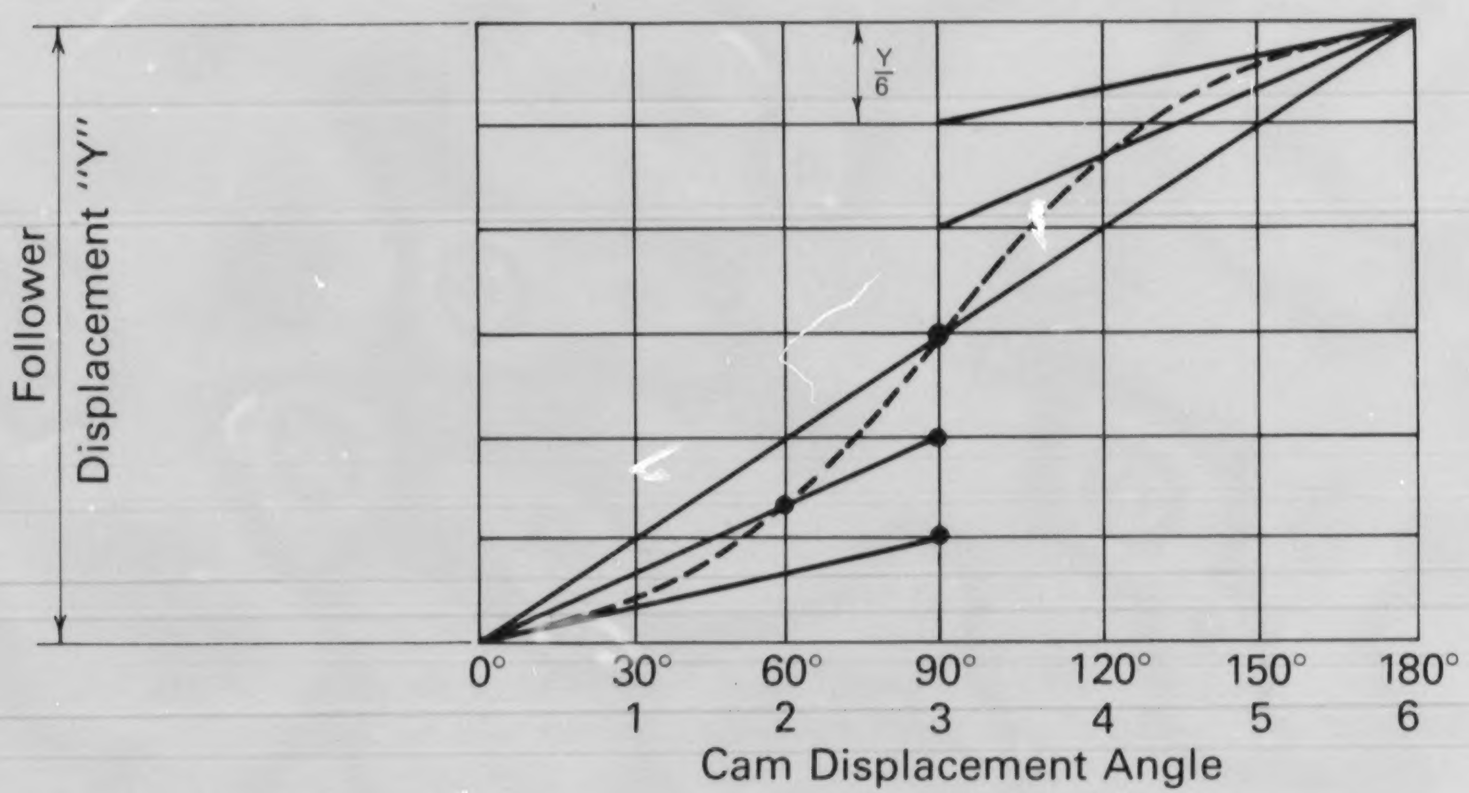

Follower
Displacement "Y"
1
3
5
5
3
1
0°
30°
60°
90°
120°
150°
180°
1
2
3
4
5
6
Cam Displacement Angle

Parabolic Motion - Cam Profile

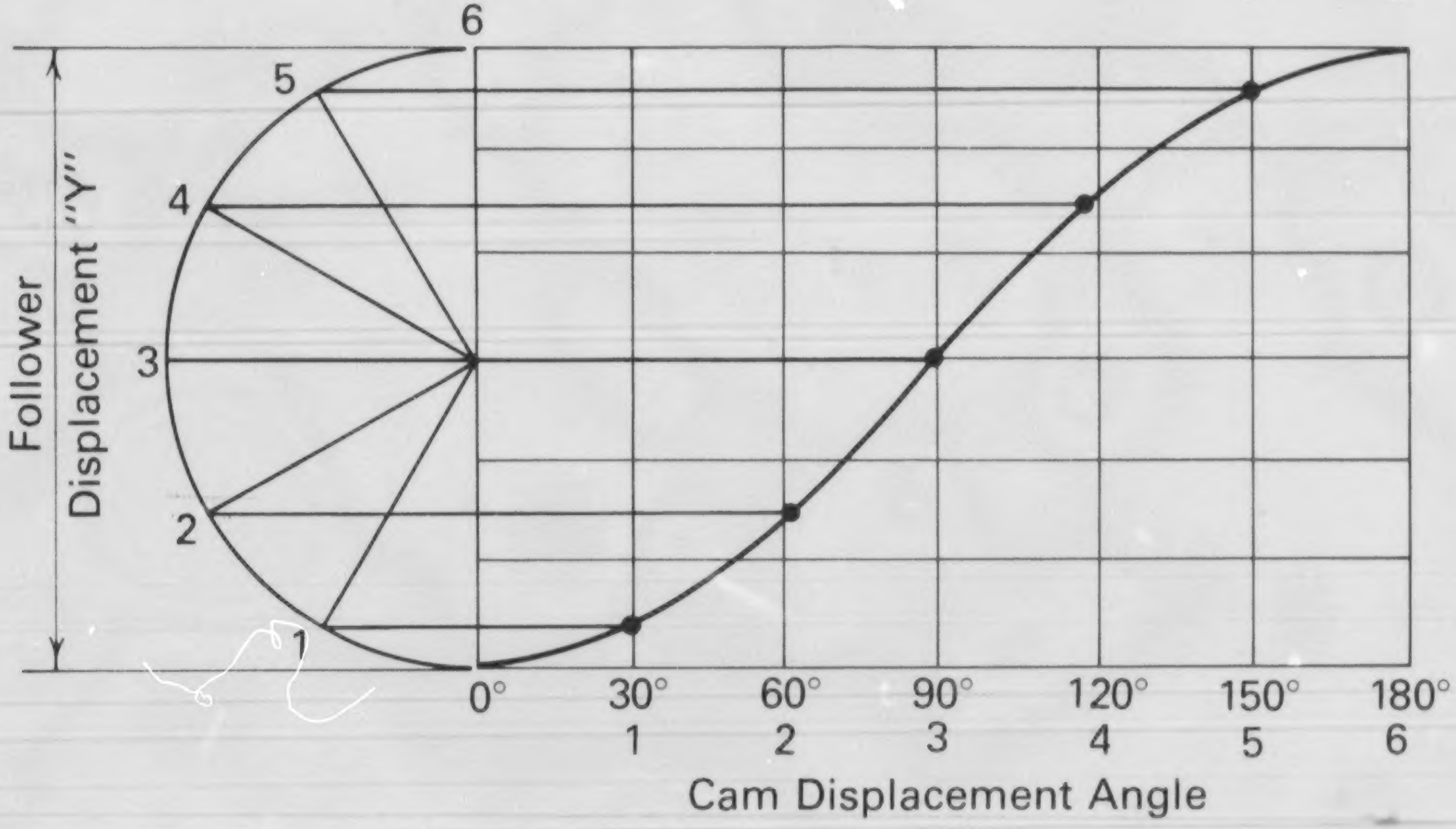

$2^2 = 4$
Base Circle
1
4
2
1
3
2
1
9
9
$3^2 = 9$
4
1
1^2
0°
60°
120°
180°
240°
300°
360°
Follower Displacement
30°
0°
330°
60°
300°
Base Circle
90°
270°
120°
240°
150°
210°
180°

Parabolic Motion

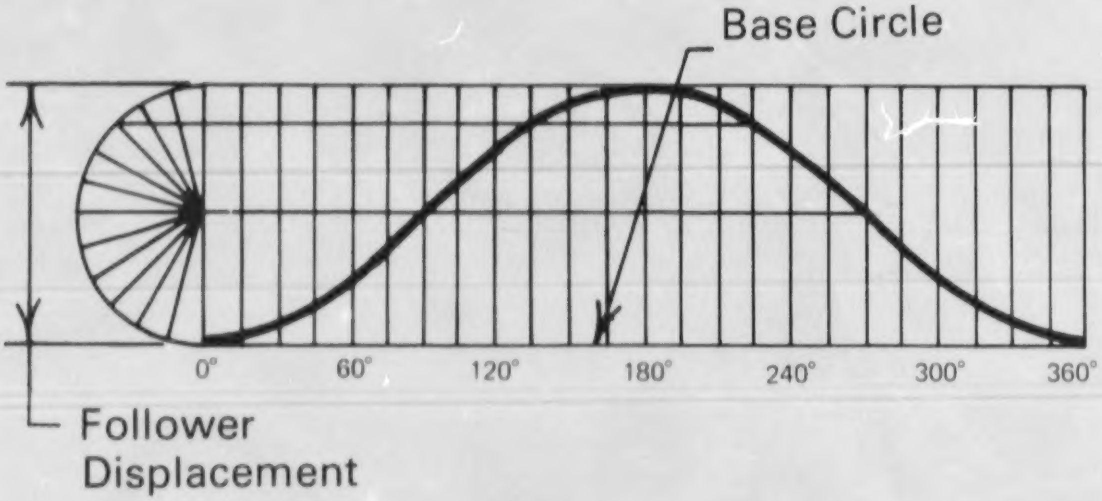
Construction Method

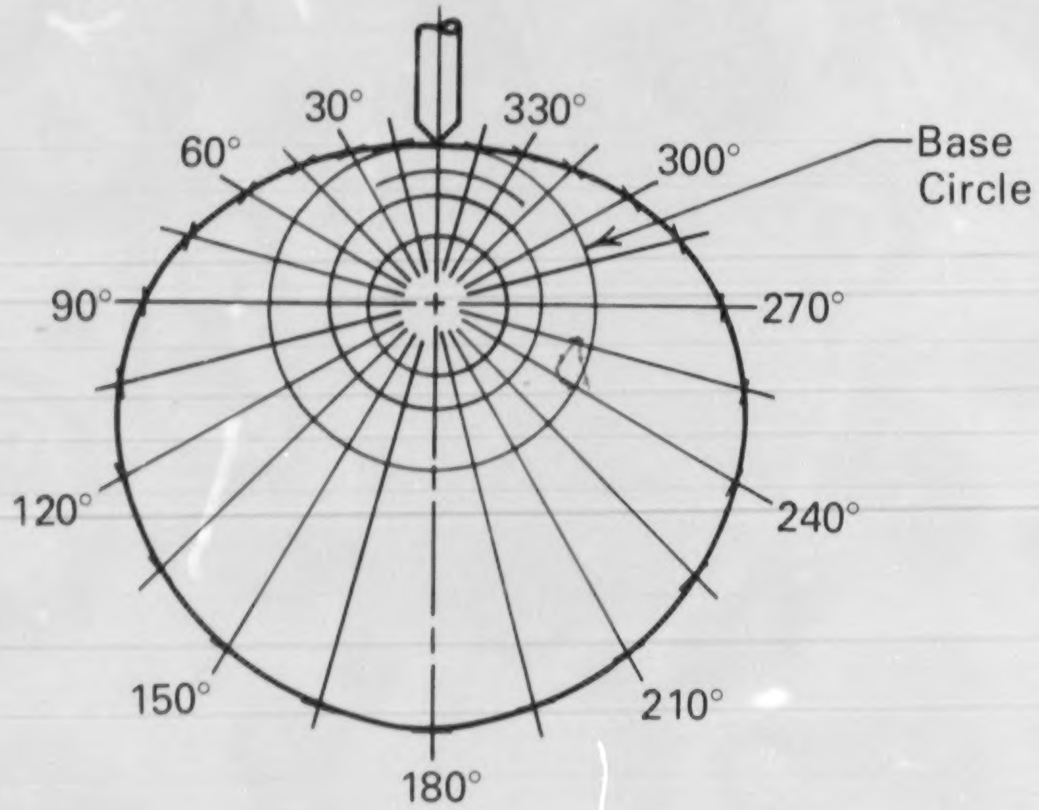

Y
6
Follower Displacement "Y"
0°
30°
60°
90°
120°
150°
180°
1
2
3
4
5
6
Cam Displacement Angle

Harmonic Motion

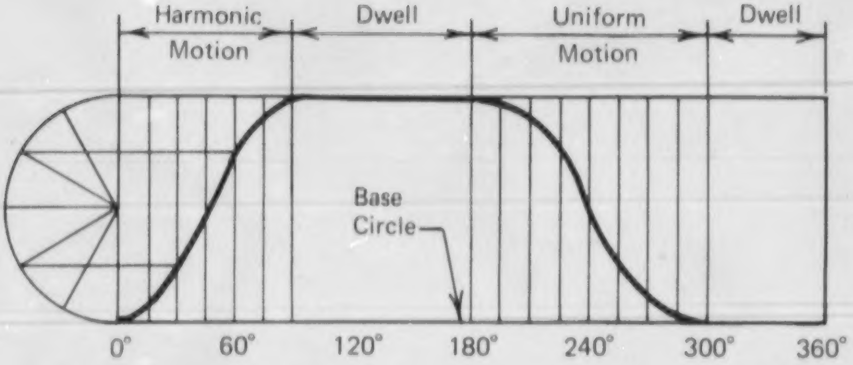

6
5
4
3
2
1
Follower Displacement "Y"
0°
30°
60°
90°
120°
150°
180°
1
2
3
4
5
6
Cam Displacement Angle

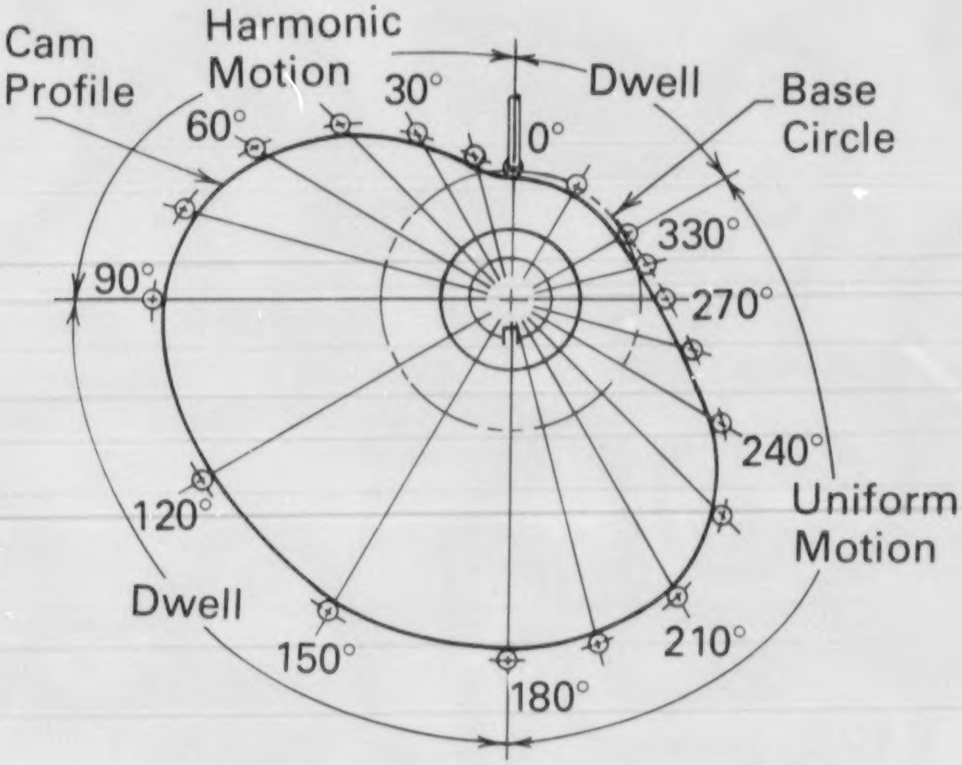
Harmonic Motion - Cam Profile


Base Circle
0°
60°
120°
180°
240°
300°
360°
Follower
Displacement


30°
330°
60°
300°
Base
Circle
90°
270°
120°
240°
150°
210°
180°

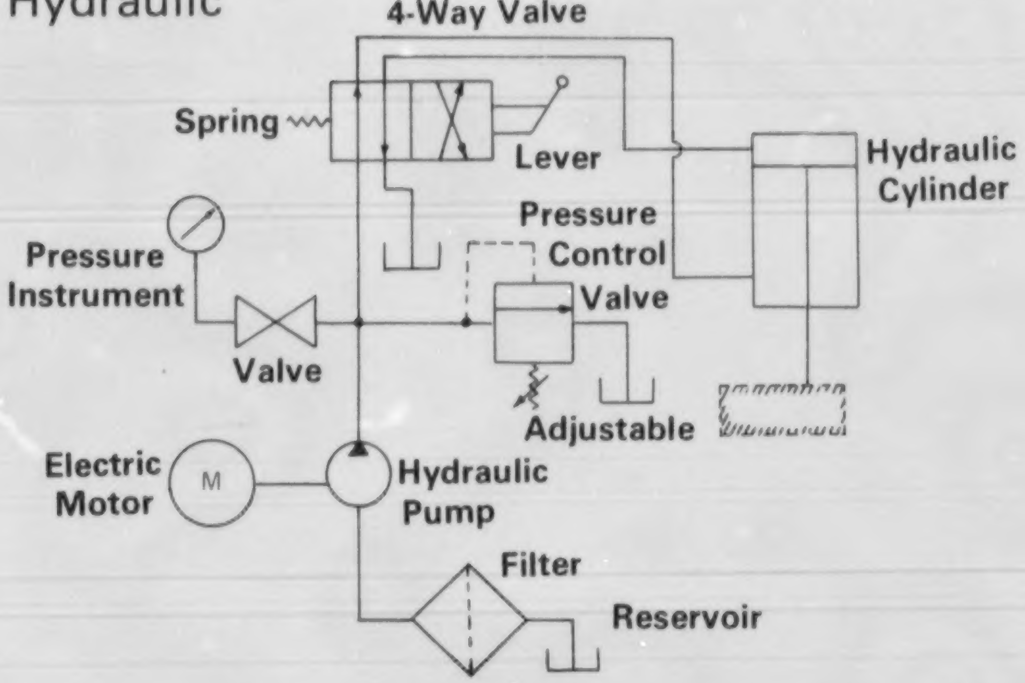
Combination of Motions


Harmonic Motion
Dwell
Uniform Motion
Dwell
Base Circle
0°
60°
120°
180°
240°
300°
360°

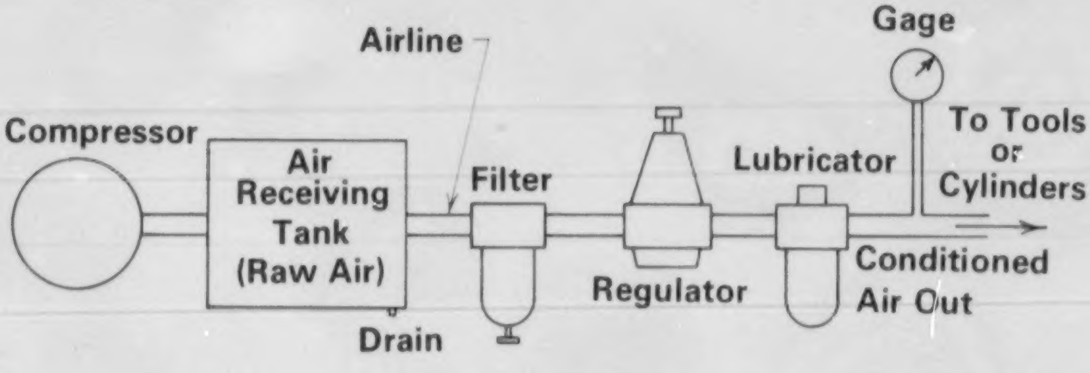

Cam Profile
Harmonic Motion
30°
60°
Dwell
0°
Base Circle
330°
90°
270°
240°
120°
Uniform Motion
Dwell
150°
180°
210°

Basic Hydraulic and Pneumatic Components

Hydraulic


4-Way Valve
Spring
Lever
Hydraulic Cylinder
Pressure Instrument
Pressure Control Valve
Valve
Adjustable
Electric Motor
M
Hydraulic Pump
Filter
Reservoir

Pneumatic


Pressure Gage
Airline
Compressor
Air Receiving Tank (Raw Air)
Filter
Lubricator
To Tools or Cylinders
Regulator
Conditioned Air Out
Drain

POWER TRANSMISSION
UNIT XI

ASSIGNMENT SHEET #1--CONSTRUCT A SPUR GEAR DRAWING

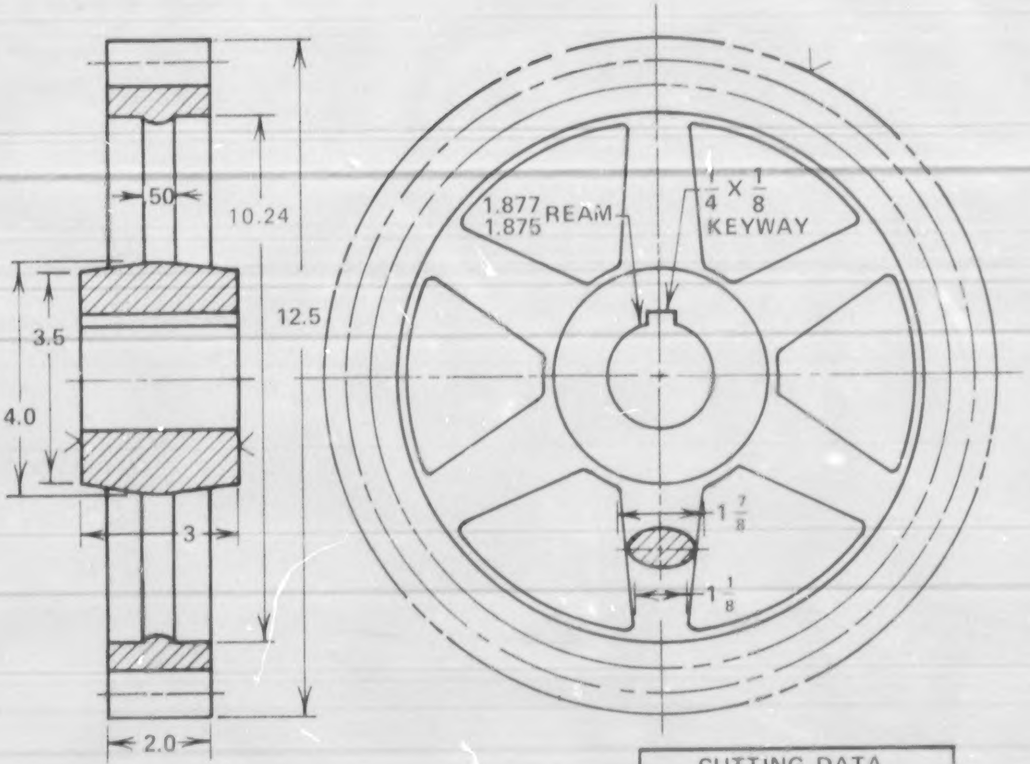
Directions: Select one of the following problems, and construct a spur gear drawing as shown in the example. Use "B" size vellum or other media assigned by instructor. Include cutting data table and dimensions. Use the following formulas to solve the incomplete cutting data in the problems:

1. No. of teeth = Pitch diameter x Diametral pitch
2. $\text{Pitch diameter} = \dfrac{\text{No. of teeth}}{\text{Diametral pitch}}$
3. $\text{Diametral pitch} = \dfrac{\text{No. of teeth}}{\text{Pitch diameter}}$
4. $\text{Whole depth} = \dfrac{2.157}{\text{Diametral pitch}}$
5. $\text{Chordal addendum} = \text{Addendum} + \dfrac{(1.57/\text{Diametral pitch})^2}{4\ (\text{Fitch diameter})}$
6. $\text{Chordal thickness} = \text{Pitch diameter}\ \dfrac{(\text{Sin } 90^\circ)}{\text{No. of teeth}}$

   (NOTE: Your instructor may wish for you to do both problems or assign another problem.)

ASSIGNMENT SHEET #1

Example:


.50
10.24
12.5
3.5
4.0
3
2.0
$\frac{1.877}{1.875}$ REAM
$\frac{1}{4} \times \frac{1}{8}$ KEYWAY
$1\frac{7}{8}$
$1\frac{1}{8}$

ROUNDS AND FILLETS $\frac{1}{8}$ R

CUTTING DATA	
NO. OF TEETH	48
PITCH DIAMETER	12.00
DIA PITCH	4.00
PRESSURE ANGLE	14½°
WHOLE DEPTH	.5395
CHORDAL ADD	.25
CHORDAL THICK	.3927
WORKING DEPTH	.5000
CIRCULAR THICK	.3927

ASSIGNMENT SHEET #1

Problems:

A. Spur gear

1. Hub thickness - 1.5"
2. Hub diameter - 2.19" at crown
3. Hub diameter - 2" at face
4. Web thickness - .31"
5. Web width at hub - .75"
6. Outside diameter - 6.4
7. Inside diameter - 5.0
8. Ream - 1.000/1.002 and keyway - 1/4 x 1/8
9. Cutting data
   a. Number of teeth - 30
   b. Pitch diameter - 6.000
   c. Diametral pitch - 5.0
   d. Pressure angle - 14 1/2°
   e. Whole depth - .431
   f. Chordal addendum ______________________________

B. Spur gear

1. Hub thickness - 2.00
2. Hub diameter - 3.00 at crown
3. Hub diameter - 2.85 at face
4. Web thickness - .50
5. Web width at hub - 1.50
6. Web width at gears - .88
7. Outside diameter - 12.25
8. Inside diameter - 8.5

ASSIGNMENT SHEET #1

9. Cutting data

   a. Number of teeth - 96

   b. Pitch diameter ____________________

   c. Diametral pitch - 8

   d. Pressure angle - 14 1/2°

   e. Whole depth ____________________

   f. Chordal addendum ____________________

POWER TRANSMISSION
UNIT XI

ASSIGNMENT SHEET #2--CONSTRUCT A BEVEL GEAR

Directions: On "B" size vellum or other media assigned by instructor, construct a bevel gear drawing from the information in problem A. Include a cutting data table and dimensions as shown in the example. On a second sheet of vellum or other media, complete the information in problem B. Use the following formulas to complete the data in problem B.

1. Number of teeth in pinion--n
2. Number of teeth in gear--N
3. Diametral pitch--P
4. Pressure angle and form--Basic is 20° = ϕ

   (NOTE: 14 1/2° pressure angle can be used, but certain combinations of teeth must be used to avoid undercutting.)

5. Addendum for gear = $\frac{\text{1 or select from table}}{\text{Diametral pitch}}$

   (NOTE: Use *Machinery's Handbook* for table.)

6. Addendum for pinion = Working depth - Addendum for gear
7. Addendum--a = $\frac{1}{\text{Diametral pitch}}$
8. Root angle--R = Pitch angle - Dedendum angle
9. Face angle--F = Pitch angle - Addendum angle
10. Whole depth--W = Addendum + Dedendum

    (NOTE: This is the same for pinion and gear.)

11. Chordal Addendum for Pinion--C_P = Addendum for pinion +

    $\frac{\text{Circular thickness for pinion x Cosine of pitch angle of pinion}}{\text{4 x Pitch diameter of pinion}}$

12. Chordal Addendum for Gear--C_G = Addendum for gear +

    $\frac{\text{Circular thickness for gear - Cosine of pitch angle of pinion}}{\text{4 x Pitch diameter of gear}}$

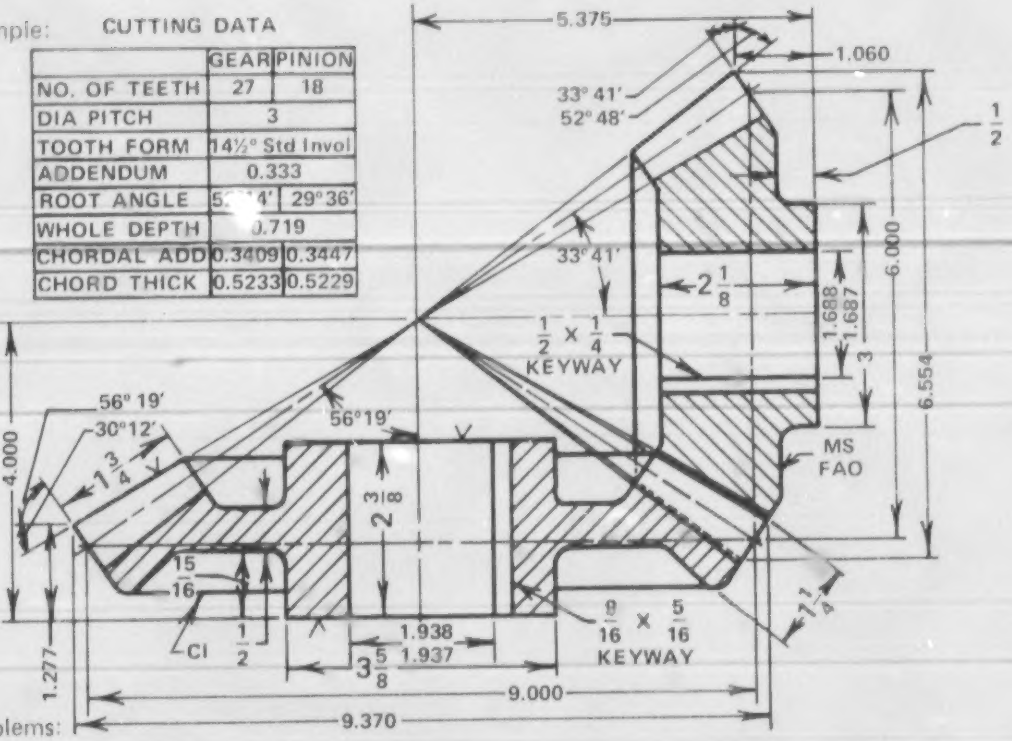
13. Chordal Thickness--C_T = Circular thickness of pinion —

    $\frac{(\text{Circular thickness of pinion})^3}{6(\text{Pitch diameter of pinion})^2} - \frac{\text{Select from Table}}{2}$

ASSIGNMENT SHEET #2

Example: **CUTTING DATA**

	GEAR	PINION
NO. OF TEETH	27	18
DIA PITCH	3	
TOOTH FORM	14½° Std Invol	
ADDENDUM	0.333	
ROOT ANGLE	5[illegible]4'	29° 36'
WHOLE DEPTH	0.719	
CHORDAL ADD	0.3409	0.3447
CHORD THICK	0.5233	0.5229


5.375
1.060
33° 41'
52° 48'
1/2
33° 41'
2 1/8
1.688
1.687
3
6.000
6.554
1/2 X 1/4
KEYWAY
MS
FAO
56° 19'
30°12'
1 3/4
56°19'
4.000
2 3/8
15/16
CI
1/2
1.277
1.938
1.937
3 5/8
9/16 X 5/16
KEYWAY
1 1/4
9.000
9.370

Problems:

(NOTE: Your instructor may wish to assign an alternate problem.)

A. Bevel gear--Draw gear only

1. Number of teeth - 20
2. Diametral pitch - 5
3. Pressure angle - 14 1/2° INV
4. Addendum - .20
5. Root angle - 40° 25'
6. Whole depth - .431
7. Chordal addendum - .204
8. Outside diameter - 4.282
9. Pitch angle - 48°
10. Pitch diameter - 4"
11. Chordal thickness - .314
12. Backing - .707
13. Back angle - 42°
14. Face - .9375
15. Face angle - 53° 03'
16. Keyway - 3/16 x 3/32
17. Mounting distance - 2.563
18. Hole size - $\frac{.875}{.877}$ DIA
19. Hub size - 1.5 DIA
20. Web thickness - .5625
21. Hub projection - .1875
22. Material - Cast Iron

ASSIGNMENT SHEET #2

B. Complete the following cutting data table using the given information.

CUTTING DATA		
	Gear	Pinion
No. of Teeth	30	20
Diametral Pitch	5	
Pressure Angle	14 1/2°	
Whole depth		
Root angle		
Face angle		
Chordal Thickness		
Addendum		

POWER TRANSMISSION
UNIT XI

ASSIGNMENT SHEET #3--CONSTRUCT A WORM AND WORM GEAR

Directions: On "B" size vellum or other media assigned by instructor, construct a worm gear. Include cutting data table and dimensions. On a second sheet of media, construct a worm. Use the following formulas to solve the incomplete cutting data in the problems.

A. Cutting data for worm

1. Number of threads--n
2. Pitch--P
3. Pitch diameter--D = (2.4 x Pitch) + 1.1

   (NOTE: This is a recommended value.)
4. Lead and direction--Distance thread moves in one revolution; RH or LH

   (NOTE: In a single thread, lead = pitch; in a double thread, lead = 2 pitch.)
5. Lead angle--Tangent $\lambda = \frac{\text{Lead}}{\pi(\text{Pitch diameter})}$
6. Pressure angle--20° or 14 1/2°
7. Whole depth--W = .686 x Pitch
8. Outside diameter--OD = Pitch diameter + .636 x Pitch
9. Face length--F = Pitch $\left(4.5 + \frac{\text{Number of teeth on gear}}{50}\right)$

B. Cutting data for worm wheel (gear)

1. Number of teeth = n
2. Pitch--P
3. Pitch diameter--D = Pitch $\left(\frac{\text{number of teeth}}{\ }\right)$
4. Addendum--a = 3.183 x Pitch
5. Whole depth--W = .686 x Pitch
6. Number of threads = t
7. Lead and direction--Distance thread moves in one turn; RH or LH
8. Lead angle--tangent $\lambda = \frac{\text{Lead}}{\pi(\text{Pitch diameter})}$

ASSIGNMENT SHEET #3

9. Pressure angle--20° or 14 1/2°

10. Throat diameter--TD = Pitch diameter + .636 x Pitch

11. Outside diameter--OD = Throat diameter + .4775 x Pitch

12. Face radius--R_F = 1/2 Pitch diameter of worm - .318 x Pitch

13. ~~Rim radius--R_r = 1/2 Pitch diameter of worm + Pitch~~

14. Face width--F = 2.38 x Pitch + .25

15. Center distance--C = 1/2(Pitch diameter of wheel + Pitch diameter of worm)

Problems:

(NOTE: Your instructor may wish to assign an alternate problem.)

A. Worm data--Complete data and draw

1. Number of threads per inch - 2
2. Pitch - .500
3. Pressure angle - 14 1/2°
4. Lead angle - 7° 53'
5. Right hand lead - 1
6. Whole depth ________________________________
7. Addendum - .159
8. OD - 2.618
9. Pitch diameter - 2.3
10. Face length ________________________________

(NOTE: Gear has 36 teeth.)

B. Worm wheel data--Complete data and draw

1. Number of teeth - 36
2. Addendum - .159
3. Whole depth - .343
4. Number of threads - 2
5. Pitch - .500

ASSIGNMENT SHEET #3

6. Pressure angle - 14 1/2°
7. Lead angle - 7° 53'
8. Right hand lead - 1
9. OD - 6.287
10. Throat diameter ______________________________
11. Pitch diameter ______________________________
12. Face radius - .99 R
13. Rim radius ______________________________
14. Hub width - 2"
15. Hub diameter - 2.125
16. Hole in hub - $\genfrac{}{}{0pt}{}{1.004}{1.000}$
17. Keyway - 1 1/4 x 1/8
18. Web thickness - .5

POWER TRANSMISSION
UNIT XI

ASSIGNMENT SHEET #4--CALCULATE GEAR RATIOS

Directions: Using the information sheet, calculate the gear ratio of the gears below and write the correct answers in blanks provided.

Problems:

A. Calculate gear ratio from information given

1. Driven gear has 9 teeth
   Driving gear has 36 teeth

   What is the gear ratio? ____________________

2. Driven gear has 36 teeth
   Driving gear has 48 teeth

   What is the gear ratio? ____________________

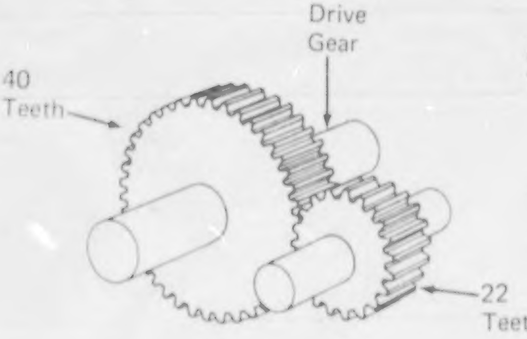
3. Driven gear has 36 teeth
   Driving gear has 12 teeth

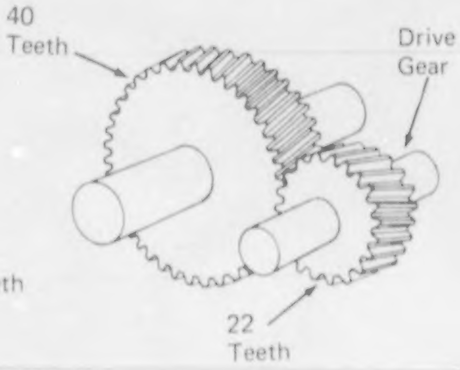
   What is the gear ratio? ____________________

4. Driven gear has 50 teeth
   Driving gear has 50 teeth

   What is the gear ratio? ____________________

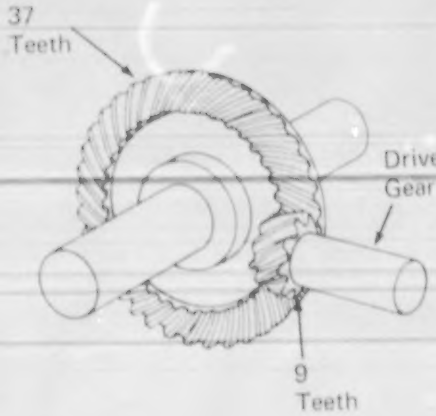
B. Calculate gear ratio from illustrations below



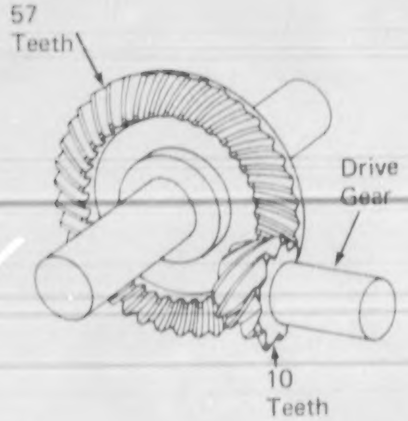


1. ____________________ 2. ____________________

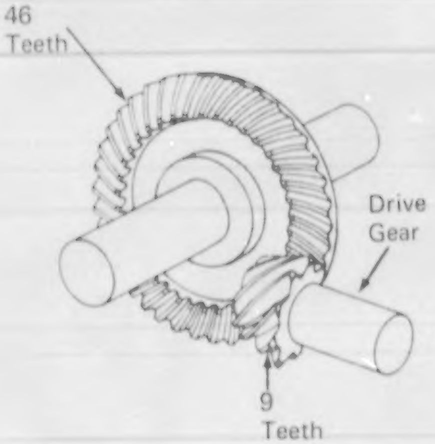
ASSIGNMENT SHEET #4


37
Teeth
Drive
Gear
9
Teeth

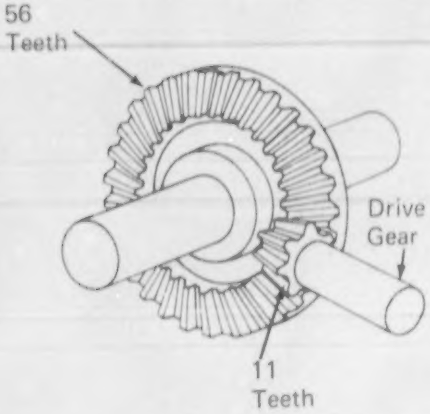
3. ______________________________


57
Teeth
Drive
Gear
10
Teeth

4. ______________________________


46
Teeth
Drive
Gear
9
Teeth

5. ______________________________


56
Teeth
Drive
Gear
11
Teeth

6. ______________________________

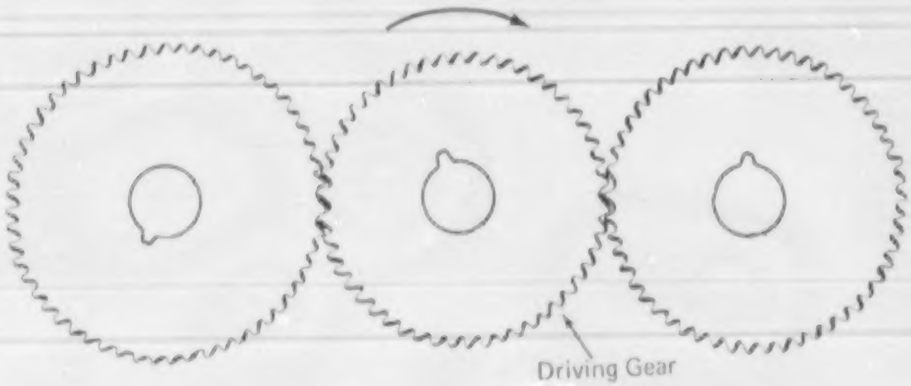
POWER TRANSMISSION
UNIT XI

ASSIGNMENT SHEET #5--DETERMINE GEAR ROTATION

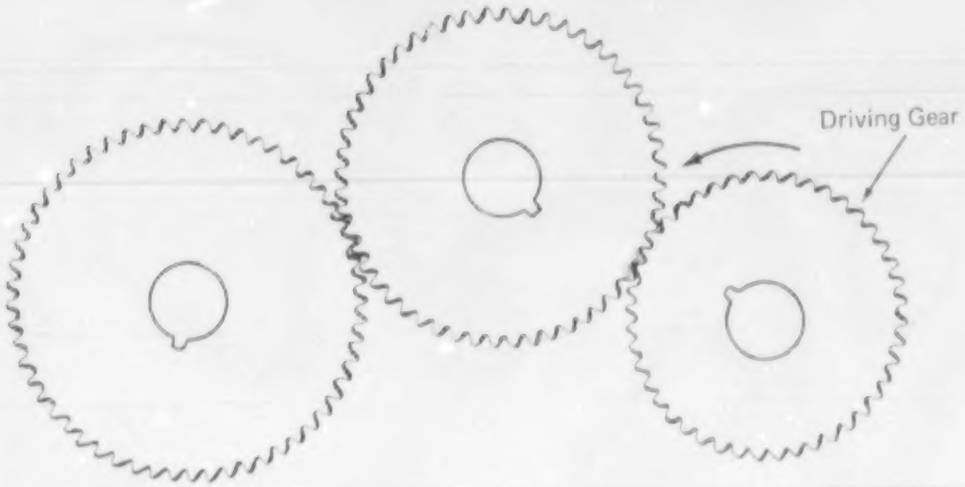
Directions: Calculate gear rotation by indicating with an arrow the direction in which the driven gears are turning.

Problems:

A.

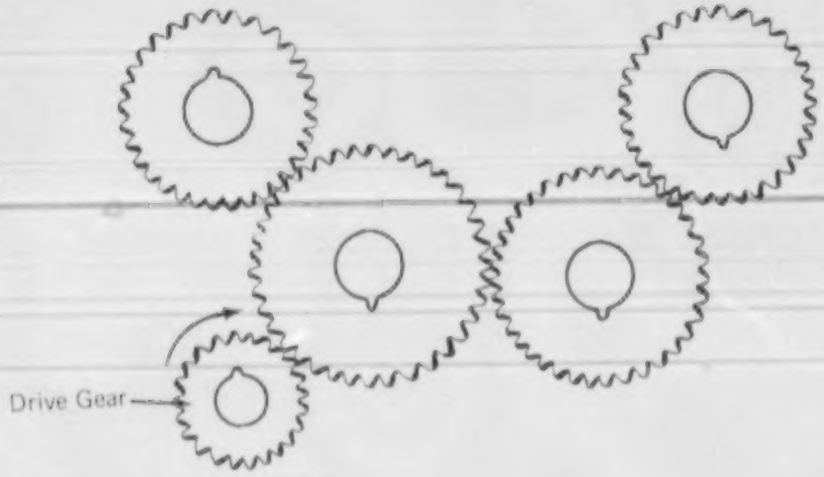

Driving Gear

B.


Driving Gear

ASSIGNMENT SHEET #5

C.



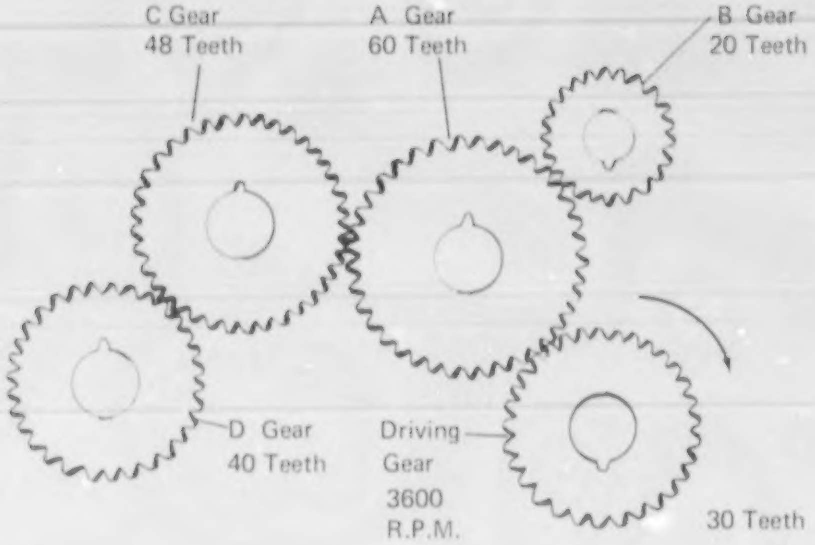
POWER TRANSMISSION
UNIT XI

ASSIGNMENT SHEET #6–CALCULATE GEAR SPEEDS

Directions: Calculate the direction of rotation, the gear ratio, and the RPM of each driven gear. Write answers in the blanks provided. For rotation, use C for clockwise and CC for counterclockwise.

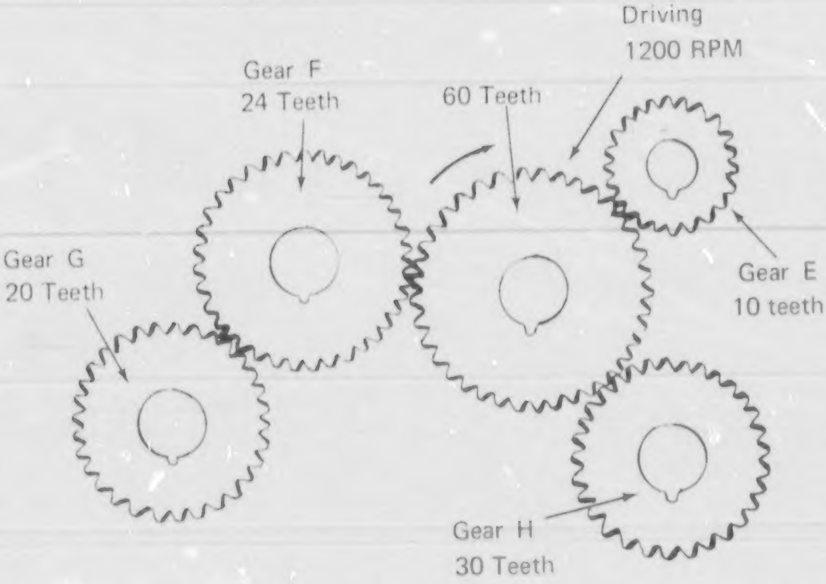
Problems:

	Rotation	Ratio	R.P.M.
A. Gear A			
B. Gear B			
C. Gear C			
D. Gear D			


C Gear
48 Teeth
A Gear
60 Teeth
B Gear
20 Teeth
D Gear
40 Teeth
Driving Gear
3600 R.P.M.
30 Teeth

ASSIGNMENT SHEET #6

		Rotation	Ratio	R.P.M.
E.	Gear E	________	________	________
F.	Gear F	________	________	________
G.	Gear G	________	________	________
H.	Gear H	________	________	________


Driving
1200 RPM
Gear F
24 Teeth
60 Teeth
Gear G
20 Teeth
Gear E
10 teeth
Gear H
30 Teeth

POWER TRANSMISSION
UNIT XI

ASSIGNMENT SHEET #7--CONSTRUCT A CAM DRAWING

Directions: On "B" size vellum or other media assigned by instructor, construct a cam drawing profile and displacement diagram for one of the following problems.

Problems:

(NOTE: Your instructor may wish to assign a different problem.)

A. Cam

1. Harmonic rise 0° through 90° to .75"
2. Dwell 90° through 180° through 360°
3. Harmonic drop 180° through 360°
4. Follower displacement 1.5"
5. Roller follower diameter .5"
6. Ream .875" 3/16 x 3/32 keyway
7. Thickness .50"

B. Cam

1. Parabolic rise 0° through 60° to 1.25"
2. Dwell 60° through 90°
3. Parabolic rise 90° through 150° to 2.00"
4. Harmonic drop 150° through 260° to 1.00"
5. Modified uniform motion 260° to 360°
6. Direction of rotation--Clockwise
7. Ream .625" - 1/2 x 1/4 keyway
8. Thickness .50"

POWER TRANSMISSION
UNIT XI

ASSIGNMENT SHEET #8--SELECT A CHAIN DRIVE

Directions: In order to select a chain drive, you will need the charts which are included at the end of this assignment sheet. Use the following example as a guideline for solving the problems.

Example problem: Select a roller chain drive to transmit 5 HP from a countershaft to the main shaft of a barking drum of a paper mill. The input is on electric motor operating to countershaft at 1200 RPM. Both shafts are 1.5" in diameter to be located approximately 22 1/2" from center to center. The barking drum puts uneven demands on the output shaft. A design of 378 to 382 RPM on the output is needed.

Example solution:

1. Determine load classification
   a. Go to load classification chart (Table 1)
   b. Locate paper mills
   c. Under paper mills, locate barking drum
   d. Read to the right under the load classification column to find "heavy shock"

      (NOTE: Uneven demands on the output shaft help to classify it as heavy shock.)
2. Determine service factor
   a. Go to service factor chart (Table 2)
   b. Under load classification, find heavy shock
   c. Read to the left under electric motor for the service factor of 1.5
3. Determine design HP
   a. Multiply the application of horsepower by the service factor to obtain equivalent design HP
   b. 5 x 1.5 = 7.5 HP

      (NOTE: For stainless steel chains, multiply the design HP by a factor from the application condition table--Table 3.)
4. Determine chain size
   a. Go to chain selection table (Table 4)

ASSIGNMENT SHEET #8

b. Find the intersection of the columns of design horsepower at 7 1/2 and RPM of smaller sprocket at 1200

(NOTE: 1200 RPM falls into the category of 1150-1399 RPM.)

c. Chain size is #40

5. Determine minimum size sprocket

a. Go to HP ratings for ANSI roller chains table (Table 5)

b. Using chart for No. 40 and 1/2" pitch, read down 1200 RPM column to 7.27

(NOTE: This is as close to your design HP of 7.5 as there is.)

c. Read left on 7.27 column to 19 teeth

(NOTE: Check the maximum bore to accommodate the 1 1/2" shafts.)

6. Calculate speed ratio

a. $\frac{\text{Maximum input RPM}}{\text{Maximum output RPM}} = \frac{\text{1200 RPM}}{\text{382 RPM}}$

b. Speed ratio is 3.12 RPM minimum

7. Find center distance and length

a. Using Speed ratio chart (Table 6), read down teeth on driver sprocket column to 19

b. Read across ratio on 19 to a number close to your ratio of 3.12; this is 3.16 on the chart

c. Read up from 3.12 to see that there are 60 teeth on the driven sprocket

d. Center distance (CD) in same box with 3.12 is 23.332

e. Length in same box with 3.12 is 88

(NOTE: Center distance and length are expressed in pitches in this chart. You will need to convert these to feet or inches.)

8. Convert pitches to inches

a. Length x pitch = 88 x 1/2

b. Chain length in inches = 44"

c. Center distance x pitch = 23.332 x 1/2

d. Center distance in inches = 11.67"

(NOTE: Stop here if center to center distance is not important.)

ASSIGNMENT SHEET #8

9. Calculate chain length for center to center distance

    a. Since a set center distance has been established of 22 1/2" in this problem, the following calculations must be made to determine the chain length

    b. Chain length in pitches = $\frac{2\text{ (set center distance)}}{\text{Pitch}} +$

    $$\frac{\text{Total number teeth on both sprockets + constant}^*}{2}$$

    *Constant
    If ratio is up to 4:1, use 2
    4 to 6:1, use 4
    6 to 8:1, use 6

    (NOTE: Ratio in this example is 3.12 which is up to 4:1, so use 2.)

    c. Chain length in pitches = $\frac{2\,(22.5)}{.5} + \frac{19 + 60}{2} + 2^*$

    $$= \frac{45.0}{.5} + \frac{79}{.2} + 2$$

    $$= 90 + 39.5 + 2 = 131.5$$

    (NOTE: Round to 132 pitches since 22 1/2 center distance is not absolutely critical.)

    d. Chain length in inches = Chain length in pitches x pitch

    = 132 (.5)

    = 66" chain length at 22.5" approximate center distance

    (NOTE: It must be remembered that more than one combination of sockets and chain will give acceptable results.)

Problems:

A. A conveyor belt, uniformly loaded is to be driven at approximately 40 RPM by a speed reducer powered by a 5 HP electric motor. The output shaft is 1 5/8" diameter reduced to 100 RPM by a speed reducer. The shaft diameter of the conveyor belt is 1 7/8". Select a center distance of not greater than 27". Select a chain length and center distance.

B. A rotary gear type of lubrication pump in a hydraulic press is driven from a 1 3/8" diameter shaft at 750 RPM. The driver rated at 3 HP has a shaft diameter of 1 1/4" operating at 1200 RPM. Center distance must not be less than 12". Select a center distance and belt length.

ASSIGNMENT SHEET #8

Table 1
Load Classification Chart

Type of Machine to be driven	Table #1 Load Classification	Table #2 Class of Service Number	
	For Helical Base Mounted Reductors, Worm Gear Reductors & Ratiomotors and Roller Chain Drives	For Helical Shaft Mounted Reductors & Ratiomotors and Base-Mounted Ratiomotors	
		3 to 10 hours/day service	Over 10 hours/day service
Agitators			
Pure Liquids	Uniform	I	II
Liquids and Solids	Moderate Shock	II	II
Liquids – Variable Density	Moderate Shock	II	II
Blowers			
Centrifugal	Uniform	I	II
Lobe	Moderate Shock	II	II
Vane	Uniform	I	II
Brewing and Distilling			
Bottling Machinery	Uniform	I	II
Brew Kettles – Continuous Duty	Uniform		II
Cookers – Continuous Duty	Uniform		II
Mash Tubs – Continuous Duty	Uniform		II
Scale Hopper – Frequent Starts	Moderate Shock	II	II
Can Filling Machines	Uniform	I	II
Cane Knives	Moderate Shock	II	II
Car Dumpers	Heavy Shock	III	
Car Pullers	Moderate Shock	I	
Clarifiers	Uniform	I	II
Classifiers	Moderate Shock	II	II
Clay Working Machinery			
Brick Press	Heavy Shock	III	III
Briquette Machine	Heavy Shock	III	III
Clay Working Machinery	Moderate Shock	II	II
Pug Mill	Moderate Shock	II	II
Compressors			
Centrifugal	Uniform	I	II
Lobe	Moderate Shock	II	II
Reciprocating Multi-cylinder	Moderate Shock	II	II
Reciprocating Single-cylinder	Heavy Shock	III	III
Conveyors – Uniformly Loaded or Fed			
Apron or Assembly	Uniform	I	II
Belt, Bucket or Chain	Uniform	I	II
Flight	Uniform	I	II
Oven or Screw	Uniform	I	II
Conveyors – Heavy Duty not Uniformly Fed			
Apron	Moderate Shock	II	II
Assembly	Moderate Shock	II	II
Belt, Bucket or Chain	Moderate Shock	II	II
Flight or Oven	Moderate Shock	II	II
Reciprocating or Shaker	Heavy Shock	III	III
Screw	Moderate Shock	II	II
Crusher			
Ore	Heavy Shock	III	III
Stone	Heavy Shock	III	III
Elevators			
Bucket – Uniform Load	Uniform	I	II
Bucket – Heavy Load	Moderate Shock	II	III
Bucket – Continuous Duty	Uniform	I	II
Centrifugal Discharge	Uniform	I	II
Freight	Moderate Shock	II	II
Gravity Discharge	Uniform	I	II
Feeders			
Apron or Belt	Moderate Shock	II	II

Courtesy of Boston Gear/Incom International Inc.

ASSIGNMENT SHEET #8

Table 1 (Continued)
Load Classification Chart

Type of Machine to Be Driven	Table #1 Load Classification	Table #2 Class of Service Number	
	For Helical Base-Mounted Reductors, Worm Gear Reductors & Ratiomotors and Roller Chain-Drives	For Helical Shaft-Mounted Reductors & Ratiomotors and Base-Mounted Ratiomotors	
		3 to 10 hours/day service	Over 10 hours/day service
Disc	Uniform	I	II
Reciprocating	Heavy Shock	III	III
Screw	Moderate Shock	II	II
Food Industry			
Beet Slicer	Moderate Shock	II	II
Cereal Cooker	Uniform	I	II
Dough Mixer or Meat Grinder	Moderate Shock	II	II
Generators (not welding)	Uniform	I	II
Hammer Mills	Heavy Shock	III	III
Hoists			
Heavy Duty	Heavy Shock	III	III
Medium Duty or Skip Type	Moderate Shock	II	II
Laundry Tumblers	Moderate Shock	II	III
Line Shafts			
Heavy Shock Load	Heavy Shock	III	III
Moderate Shock Load	Moderate Shock	II	II
Uniform Load	Uniform	I	I
Machine Tools			
Bending Roll	Moderate Shock	II	II
Punch Press – Gear Driven	Heavy Shock	III	III
Plate Planers	Heavy Shock	III	III
Tapping Machine	Heavy Shock	III	III
Other Machine Tools			
Main Drives	Moderate Shock	II	II
Auxiliary Drives	Uniform	I	II
Metal Mills			
Draw Bench Carriage and Main Drive	Heavy Shock	III	III
Slitters	Moderate Shock	II	II
Table Conveyors			
Non Reversing	Moderate Shock	II	III
Reversing	Moderate Shock	—	III
Wire Drawing and Flattening Machine	Moderate Shock	II	III
Wire Winding Machine	Moderate Shock	II	II
Mills, Rotary Type			
Ball	Heavy Shock	III	III
Dryers and Coolers	Moderate Shock	II	II
Kilns	Moderate Shock	II	II
Pebble	Heavy Shock	III	III
Rod, Plain and Wedge Bar	Heavy Shock	III	III
Mixers			
Concrete Mixers			
Continuous Duty	Moderate Shock	II	II
Intermittent Duty	Moderate Shock	I	—
Constant Density	Uniform	I	II
Variable Density	Moderate Shock	II	II
Paper Mills			
Agitators (Mixers)	Moderate Shock	II	II
Barker — Auxiliaries — Hydraulic	Moderate Shock	—	III
Barker — Mechanical	Moderate Shock	—	III
Barking Drum	Heavy Shock	—	III
Beater and Pulper	Moderate Shock	—	II
Bleacher	Uniform	—	II
Calendars	Moderate Shock	—	II
Calendars — Super	Moderate Shock	—	II
Converting Machine, Except Cutters, Platers	Moderate Shock	—	II
Conveyors	Uniform	—	II
Couch —	Moderate Shock	—	II

Courtesy of Boston Gear/Incom International Inc.

ASSIGNMENT SHEET #8

Table 1 (Continued)
Load Classification Chart

Type of Machine to Be Driven	Table #1 Load Classification	Table #2 Class of Service Number	
	For Helical Base-Mounted Reductors, Worm Gear Reductors & Ratiomotors and Roller Chain-Drives	For Helical Shaft-Mounted Reductors & Ratiomotors and Base-Mounted Ratiomotors	
		3 to 10 hours/day service	Over 10 hours/day service
Cutters — Platers	Heavy Shock	—	III
Cylinders or Dryers	Moderate Shock	—	II
Felt Stretcher	Moderate Shock	—	II
Felt Whipper	Heavy Shock	—	III
Jordans	Uniform	—	II
Log Haul	Heavy Shock	—	III
Presses	Uniform	—	II
Pulp Machine Reel	Moderate Shock	—	II
Stock Chests	Moderate Shock	—	II
Suction Roll	Uniform	—	II
Washers and Thickeners	Moderate Shock	—	II
Winders	Uniform	—	II
Printing Presses	Uniform	I	II
Pullers			
Barge Haul	Heavy Shock	III	III
Pumps			
Centrifugal	Uniform	I	II
Proportioning	Moderate Shock	II	II
Reciprocating			
Single Acting; 3 or more Cylinders	Moderate Shock	II	II
Double Acting, 2 or more Cylinders	Moderate Shock	II	II
Rotary — Gear, Lobe or Vane Type	Uniform	I	II
Rubber and Plastics Industries			
Mixing Mills	Heavy Shock	III	III
Rubber Calendars or Sheeters	Moderate Shock	II	II
Sewage Disposal Equipment			
Bar Screens	Uniform	I	II
Chemical Feeders	Uniform	I	II
Collectors	Uniform	I	II
Dewatering Screens	Moderate Shock	II	II
Scum Breakers	Moderate Shock	II	II
Slow or Rapid Mixers	Moderate Shock	II	II
Thickeners	Moderate Shock	II	II
Vacuum Filters	Moderate Shock	II	II
Screens			
Air Washing	Uniform	I	II
Rotary — Stone or Gravel	Moderate Shock	II	II
Traveling Water Intake	Uniform	I	II
Slab Pushers	Moderate Shock	II	II
Stokers	Uniform	I	II
Textile Industry			
Batchers or Calendars	Moderate Shock	II	II
Cards	Moderate Shock	II	II
Dyeing Machinery or Dryers	Moderate Shock	II	II
Looms, Mangles, Nappers or Pads	Moderate Shock	II	II
Slashers or Soapers	Moderate Shock	II	II
Spinners	Moderate Shock	II	II
Tenters Frames	Moderate Shock	II	II
Washers or Winders	Moderate Shock	II	II
Tumbling Barrels	Heavy Shock	III	III
Windlass	Moderate Shock	II	II

Table 2
Service Factor Table

Load Classification	TYPE OF INPUT POWER		
	Internal Combustion Engine With Hydraulic Drive	Electric Motor With Mechanical Drive	Internal Combustion Engine With Mechanical Drive
Uniform	1.0	1.0	1.2
Moderate Shock	1.2	1.3	1.4
Heavy Shock	1.4	1.5	1.7

Courtesy of Boston Gear/Incom International Inc.

ASSIGNMENT SHEET #8

Table 3
Application Conditions Table for Stainless Steel Chains

Application Conditions	Factor
Wet	2.0
Dry	5.0

Table 4
Selection Chart

BOSTON ROLLER CHAIN SELECTION TABLE

RPM of Smaller Sprocket	DESIGN HORSEPOWER												
	1/2	1	1-1/2	2	3	4	5	7-1/2	10	15	20	25	30
	CHAIN NUMBER												
1700-2000	41	41	35	35	35	35	35	40	40	40	40-2	40-2	40-3
1400-1699	41	41	41	35	35	35	40	40	40	50	50	50-2	50-2
1150-1399	41	41	41	41	35	35	40	40	50	50	60	60	80
950-1149	41	41	41	41	35	40	40	50	50	60	60	80	80
800-949	41	41	41	41	40	40	40	50	50	60	60	80	80
650-799	41	41	41	41	40	40	40	50	50	60	80	80	80
525-649	41	41	41	40	40	40	50	50	60	80	80	80	80
425-524	41	41	40	40	40	50	50	60	60	80	80	80	100
375-424	41	41	40	40	40	50	50	60	60	80	80	100	100
325-374	41	41	40	40	50	50	50	60	80	80	80	100	100
275-324	41	40	40	40	50	50	60	60	80	80	80	100	100
225-274	41	40	40	40	50	60	60	80	80	80	100	100	120
185-224	41	40	40	50	50	60	60	80	80	100	100	120	120
160-184	41	40	50	50	60	60	80	80	80	100	100	120	120
140-159	41	40	50	50	60	60	80	80	80	100	120	120	120
120-139	40	40	50	50	60	80	80	80	100	100	120	120	140
90-119	40	50	50	60	80	80	80	100	100	120	120	140	140
75-89	40	50	60	60	80	80	80	100	100	120	140	140	160
65-74	40	50	60	60	80	80	80	100	100	120	140	160	160
55-64	40	50	60	80	80	80	100	100	120	140	140	160	—
45-54	50	60	60	80	80	100	100	120	120	140	160	160	—
35-44	50	60	80	80	100	100	100	120	140	160	160	—	—
31-34	50	60	80	80	100	100	120	120	140	160	160	—	—
26-30	50	80	80	80	100	100	120	140	140	160	—	—	—
21-25	60	80	80	100	100	120	120	140	160	160	—	—	—
16-20	60	80	100	100	120	120	140	160	160	—	—	—	—
11-15	80	80	100	120	140	140	140	160	—	—	—	—	—
5-10	80	100	120	140	160	160			—	—	—	—	—

Courtesy of Boston Gear/Incom International Inc.

ASSIGNMENT SHEET #8

Table 5
HP Ratings for ANSI Roller Chains Table

HP RATINGS – STANDARD SINGLE* STRAND ROLLERLESS CHAIN – NO. 25 – 1/4" PITCH

Small Sprocket RPM →		10	20	30	50	75	100	125	150	200	250	300	400	600	900	1200	1800	2500	3000	3500	4000
Teeth	P.D.																				
12	.97"	.007	.014	.020	.032	.046	.059	.072	.085	.11	.14	.16	.21	.29	0.43	0.55	0.80	1.07	1.26	1.45	1.62
15	1.20	.009	.018	.025	.040	.058	.075	.092	.108	.14	.17	.20	.26	.38	0.54	0.70	1.01	1.36	1.61	1.85	2.08
17	1.36	.011	.020	.029	.046	.066	.086	.105	.124	.16	.20	.23	.30	.43	0.62	0.81	1.16	1.56	1.84	2.11	2.38
19	1.52	.012	.023	.033	.052	.075	.097	.119	.140	.18	.22	.26	.34	.49	0.70	0.91	1.31	1.76	2.07	2.38	2.69
20	1.60	.013	.024	.035	.055	.079	.103	.125	.148	.19	.23	.28	.36	.52	0.74	0.96	1.38	1.86	2.19	2.52	2.84
Lubrication ≠		Type I														Type II					

HP RATINGS – STANDARD SINGLE* STRAND ROLLERLESS CHAIN – NO. 35 – 3/8" PITCH

Small Sprocket RPM →		10	20	30	50	75	100	125	150	200	250	300	400	600	900	1200	1500	1800	2500	3000
Teeth	P.D.																			
11	1.33"	.023	.043	.062	.098	.14	.18	.22	.26	.34	.42	.49	.63	.91	1.32	1.72	2.08	2.47	3.32	2.93
13	1.57	.027	.051	.074	.117	.17	.22	.27	.31	.41	.50	.59	.76	1.09	1.59	2.05	2.49	2.96	3.98	3.76
15	1.80	.032	.060	.086	.136	.20	.26	.31	.37	.47	.58	.68	.89	1.28	1.85	2.40	2.91	3.45	4.64	4.66
17	2.04	.037	.068	.099	.156	.22	.29	.36	.42	.54	.66	.78	1.02	1.46	2.12	2.75	3.33	3.95	5.31	5.63
19	2.28	.042	.077	.111	.176	.25	.33	.40	.47	.61	.75	.88	1.15	1.65	2.39	3.10	3.76	4.46	5.99	6.65
21	2.52	.046	.086	.124	.196	.28	.37	.45	.53	.68	.83	.98	1.27	1.84	2.66	3.45	4.19	4.97	6.68	7.73
23	2.75	.051	.095	.137	.217	.31	.41	.49	.58	.75	.92	1.09	1.41	2.03	2.94	3.81	4.62	5.48	7.37	8.68
25	2.99	.055	.104	.150	.237	.34	.44	.54	.64	.82	1.01	1.19	1.54	2.22	3.21	4.16	5.06	6.00	8.06	9.50
Lubrication ≠		Type I											Type II					Type III		

HP RATINGS – STANDARD SINGLE* STRAND ROLLER CHAIN – NO. 41 – 1/2" PITCH

Small Sprocket RPM →		10	20	30	50	75	100	125	150	200	250	300	400	600	900	1200	1800	2400	3000
Teeth	P.D.																		
11	1.77"	.030	.056	.080	.13	.18	.24	.29	.34	.44	.54	.64	.82	1.19	1.71	1.71	0.93	0.60	0.43
13	2.09	.036	.067	.096	.15	.22	.28	.35	.41	.53	.65	.76	.99	1.42	2.05	2.20	1.20	0.78	0.56
15	2.40	.042	.078	.112	.18	.26	.33	.40	.48	.62	.75	.89	1.13	1.66	2.39	2.73	1.49	0.96	0.69
17	2.72	.048	.089	.128	.20	.29	.38	.46	.55	.71	.86	1.02	1.32	1.90	2.74	3.29	1.79	1.16	0.83
19	3.04	.054	.100	.145	.23	.33	.43	.52	.62	.80	.97	1.15	1.49	2.14	3.09	3.89	2.12	1.38	0.98
21	3.35	.060	.112	.161	.26	.37	.48	.58	.69	.89	1.09	1.28	1.66	2.39	3.44	4.46	2.46	1.60	1.14
23	3.67	.066	.124	.178	.28	.41	.53	.64	.76	.98	1.20	1.41	1.83	2.64	3.79	4.92	2.82	1.83	1.31
25	3.99	.072	.133	.195	.31	.44	.58	.70	.83	1.07	1.31	1.55	2.00	2.88	4.15	5.38	3.20	2.08	1.49
Lubrication ≠		Type I								Type II					Type III		Type IV		

HP RATINGS – STANDARD SINGLE* STRAND ROLLER CHAIN – NO. 43 – 1/2" PITCH

Small Sprocket RPM →		10	20	30	40	50	75	100	125	150	175	200	250	300	350	400	500	600	900
Teeth	P.D.																		
11	1.77"	.030	.056	.080	.11	.13	.18	.24	.29	.34	.39	.44	.54	.64	.73	.82	1.01	1.19	1.40
13	2.09	.036	.067	.096	.13	.16	.22	.28	.35	.41	.47	.53	.65	.76	.87	.99	1.21	1.42	1.70
15	2.41	.042	.078	.112	.15	.18	.26	.33	.40	.48	.55	.62	.75	.89	1.02	1.15	1.41	1.66	2.00
16	2.56	.045	.084	.120	.16	.19	.28	.36	.43	.52	.59	.67	.81	.96	1.10	1.23	1.51	1.78	2.28
18	[illegible]	[illegible]	.095	.137	.18	.22	.31	.41	.49	.59	.67	.76	.92	1.09	1.25	1.41	1.72	2.02	2.80
20	3.20	.057	.106	.153	.20	.25	.35	.46	.55	.66	.75	.85	1.03	1.22	1.40	1.58	1.93	2.27	3.25
22	3.51	.063	.118	.170	.23	.27	.39	.51	.61	.73	.83	.94	1.15	1.35	1.55	1.75	2.14	2.52	3.62
24	3.83	.069	.130	.187	.25	.30	.42	.56	.67	.80	.91	1.03	1.26	1.48	1.70	1.92	2.35	2.76	3.97
Lubrication ≠		Type I												Type II					Type III

RATINGS FOR INTERMEDIATE NUMBERS OF TEETH OR RPM MAY BE OBTAINED BY INTERPOLATION.

Courtesy of Boston Gear/Incom International Inc.

ASSIGNMENT SHEET #8

Table 5 (continued)

HP RATINGS – STANDARD SINGLE* STRAND ROLLER CHAIN – NO. 40 – 1/2" PITCH

Small Sprocket Teeth	P.D.	RPM → 10	20	30	50	75	100	125	150	200	250	300	400	500	600	900	1200	1500	1800	2400	3000
11	[illegible]	.034	.06	.14	.23	.33	.43	.53	.62	.83	.98	1.10	1.30	1.84	2.16	3.11	4.03	4.93	4.06	3.03	2.17
13	2.09	.005	.12	.17	.28	.40	.53	.63	.76	.96	1.13	1.38	1.64	2.50	2.96	3.71	4.83	5.91	5.99	3.89	2.79
15	2.40	.035	.14	.20	.32	.46	.61	.74	.87	1.12	[illegible]	[illegible]	2.10	2.56	3.02	4.35	5.64	6.89	7.41	4.82	3.45
17	[illegible]	.067	.16	.22	.37	.53	.69	.84	.99	1.29	[illegible]	1.87	2.40	2.94	3.45	4.98	6.45	7.89	8.96	5.82	4.17
19	3.04	.088	.18	.26	.42	.60	.78	.95	1.12	1.45	[illegible]	2.09	2.71	3.31	3.90	5.62	7.27	8.89	10.5	6.88	4.92
21	3.35	.109	.20	.29	.46	.67	.87	1.06	1.25	1.62	[illegible]	2.33	3.02	3.69	4.34	6.26	8.11	9.91	11.7	7.99	5.72
23	3.67	.120	.22	.32	.51	.74	.96	1.17	1.38	1.78	[illegible]	2.57	3.33	4.07	4.79	6.90	8.94	10.9	12.9	9.16	6.55
25	3.99	.132	.24	.35	.56	.81	1.05	1.28	1.51	1.95	[illegible]	2.81	3.64	4.45	5.24	7.55	9.78	12.0	14.1	10.4	7.43
Lubrication ★		Type I								Type II						Type III		Type IV			

HP RATINGS – STANDARD SINGLE* STRAND ROLLER CHAIN – NO. 50 – 5/8" PITCH

Small Sprocket Teeth	P.D.	RPM → 10	20	30	50	75	100	125	150	200	250	300	400	600	900	1200	1500	1800	2100	2400	2700
11	[illegible]	[illegible]	.20	.28	.45	.65	.84	1.03	1.21	1.56	1.91	2.26	2.93	4.21	6.07	7.86	7.44	5.58	4.42	3.62	3.04
13	[illegible]	[illegible]	.24	.34	.54	.78	1.01	1.23	1.45	1.87	2.29	2.70	3.50	5.04	7.26	9.42	9.56	7.17	5.67	4.65	3.90
15	[illegible]	[illegible]	.28	.40	.63	.90	1.17	1.43	1.69	2.18	2.67	3.15	4.08	5.88	8.48	11.0	11.9	8.89	7.03	5.76	4.83
17	3.40	[illegible]	.32	.45	.72	1.04	1.34	1.64	1.93	2.50	3.06	3.60	4.67	6.73	9.70	12.6	14.3	10.2	8.48	6.95	5.83
19	3.80	.18	.36	.51	.81	1.17	1.51	1.85	2.18	2.82	3.45	4.06	5.27	7.59	10.9	14.2	16.9	12.7	10.0	8.22	6.89
21	4.19	.21	.40	.57	.90	1.30	1.69	2.06	2.43	3.15	3.85	4.53	5.87	8.46	12.2	15.8	19.3	14.7	11.6	9.55	8.01
23	4.59	.23	.44	.63	1.00	1.44	1.86	2.27	2.68	3.47	4.25	5.00	6.48	9.33	13.4	17.4	21.3	16.9	13.3	10.9	9.18
25	4.99	.26	.48	.69	1.09	1.57	2.04	2.49	2.93	3.80	4.64	5.47	7.09	10.2	14.7	19.1	23.3	19.1	15.1	12.4	10.4
Lubrication ★		Type I					Type II						Type III				Type IV				

HP RATINGS – STANDARD SINGLE* STRAND ROLLER CHAIN – NO. 60 – 3/4" PITCH

Small Sprocket Teeth	P.D.	RPM → 10	20	30	50	75	100	125	150	200	250	300	400	600	900	1200	1400	1600	1800	2000	2200	2400
11	[illegible]	.18	.34	.49	.78	1.12	1.44	[illegible]	[illegible]	2.60	[illegible]	3.67	5.02	7.23	10.5	11.9	9.45	7.70	6.49	5.31	4.78	4.20
13	[illegible]	.22	.41	.59	.94	1.35	1.75	[illegible]	2.48	[illegible]	3.94	4.64	6.01	8.65	12.5	15.3	12.1	9.89	8.34	7.08	6.14	5.39
15	[illegible]	.25	.47	.68	1.08	1.55	2.01	2.46	2.90	3.76	4.59	5.41	7.01	10.1	14.6	18.9	15.0	12.3	10.3	8.77	7.61	6.68
17	4.08	.29	.54	.78	1.23	1.76	2.30	2.82	3.32	4.31	5.26	6.20	8.03	11.6	16.7	21.7	18.2	14.8	12.5	10.6	9.18	8.06
19	[illegible]	.33	.61	.88	1.40	2.01	2.60	3.18	3.74	4.86	5.93	6.99	9.05	13.0	18.8	24.4	21.5	17.5	14.7	12.5	10.9	9.52
21	[illegible]	.37	.68	.98	1.56	2.24	2.90	3.54	4.17	5.41	6.61	7.78	10.1	14.5	21.0	27.2	24.9	20.3	17.1	14.5	12.6	11.1
23	[illegible]	.40	.75	1.08	1.72	2.47	3.19	3.91	4.60	5.97	7.29	8.59	11.1	16.0	23.2	30.5	28.6	23.3	19.6	16.7	14.4	12.7
25	[illegible]	.44	.82	1.18	1.88	2.70	3.49	4.28	5.04	[illegible]	7.98	9.40	12.2	17.5	25.4	32.9	32.4	26.4	22.3	18.9	16.4	14.4
Lubrication ★		Type I				Type II					Type III				Type IV							

HP RATINGS – STANDARD SINGLE* STRAND ROLLER CHAIN – NO. 80 – 1" PITCH

Small Sprocket Teeth	P.D.	RPM → 10	20	30	50	75	100	125	150	200	250	300	400	600	900	1000	1200	1400	1600	1800	2000	2200
11	3.55	.42	.79	1.14	1.80	2.60	3.36	4.11	4.84	6.28	[illegible]	9.04	[illegible]	16.9	23.0	19.6	14.9	11.8	9.69	8.12	6.94	6.01
13	4.18	.51	.95	1.36	2.16	3.11	4.03	4.92	5.80	7.52	9.19	10.8	14.0	20.2	29.1	25.2	19.2	15.2	12.5	10.4	8.91	7.72
15	4.81	.59	1.10	1.58	2.52	3.63	4.70	5.75	6.77	8.77	10.7	12.6	16.4	23.6	34.0	31.3	23.8	18.9	15.4	12.9	11.0	9.57
17	5.44	.68	1.26	1.82	2.88	4.15	5.38	6.58	7.75	10.0	12.3	14.5	18.7	27.0	38.9	37.6	28.7	22.7	18.6	15.6	13.3	11.5
19	6.08	.76	1.43	2.05	3.25	4.68	6.07	7.42	8.75	11.3	13.8	16.3	21.1	30.4	43.8	44.5	33.9	26.9	22.0	18.4	15.7	13.6
21	6.71	.85	1.59	2.29	3.62	5.22	6.76	8.27	9.74	12.6	15.4	18.2	23.6	34.0	48.9	51.7	39.4	31.2	25.6	21.4	18.3	15.9
23	7.34	.94	1.75	2.52	4.00	5.76	7.46	9.12	10.7	13.9	17.0	20.0	26.0	37.4	53.9	59.2	45.1	35.8	29.3	24.6	21.0	18.2
25	7.98	1.03	1.92	2.76	4.38	6.30	8.17	9.98	11.8	15.2	18.6	21.9	28.4	40.9	59.0	68.9	51.1	40.6	33.2	27.8	23.8	20.6
Lubrication ★		Type I			Type II						Type III			Type IV								

RATINGS FOR INTERMEDIATE NUMBERS OF TEETH OR RPM MAY BE OBTAINED BY INTERPOLATION

Courtesy of Boston Gear/Incom International Inc.

ASSIGNMENT SHEET #8

Table 5 (continued)

Small Sprocket		HP RATINGS – STANDARD SINGLE* STRAND ROLLER CHAIN – NO. 100 – 1-1/4" PITCH																	
RPM → Teeth	P.D.	10	20	30	50	75	100	125	150	200	250	300	400	500	600	900	1000	1200	1400	
11	4.43	.81	1.51	2.18	3.45	4.97	6.48	7.88	9.28	12.0	14.7	17.3	22.4	27.4	32.3	27.5	23.4	17.8	14.2	
13	5.22	.97	1.81	2.61	4.13	5.96	7.73	9.43	11.1	14.4	17.6	20.7	26.9	32.8	38.7	35.3	30.1	22.9	18.2	
15	6.01	1.13	2.12	3.05	4.82	6.95	9.00	11.0	13.0	16.8	20.6	24.3	31.4	38.4	45.3	43.7	37.3	28.4	22.5	
17	6.80	1.30	2.42	3.49	5.52	7.96	10.3	12.6	14.9	19.2	23.5	27.7	35.9	43.9	51.7	52.7	45.0	34.3	27.2	
19	7.59	1.46	2.73	3.93	6.23	8.98	11.6	14.2	16.8	21.7	26.5	31.2	40.5	49.5	58.3	63.3	53.2	40.5	32.1	
21	8.39	1.63	3.04	4.38	6.94	10.0	12.9	15.8	18.7	24.2	29.6	34.8	45.1	55.1	64.9	72.4	61.8	47.0	37.3	
23	9.18	1.80	3.36	4.84	7.67	11.0	14.3	17.5	20.6	26.6	32.6	38.4	49.7	60.8	71.7	83.0	70.9	53.9	42.8	
25	9.97	1.97	3.67	5.29	8.41	12.1	15.6	19.1	22.5	29.3	35.7	42.0	54.3	66.5	78.4	94.1	80.3	61.1	48.5	
Lubrication #		Type I			Type II		Type III						Type IV							

Small Sprocket		HP RATINGS – STANDARD SINGLE* STRAND ROLLER CHAIN – NO. 120 – 1-1/2" PITCH																	
RPM → Teeth	P.D.	10	20	30	50	75	100	125	150	200	250	300	400	500	600	700	800	900	1000	1200
11	5.324	1.37	2.56	3.68	5.83	8.40	10.9	13.3	15.6	20.3	24.8	29.2	37.8	46.3	54.5	46.1	37.9	31.8	27.1	20.6
13	6.268	1.64	3.06	4.41	6.99	10.1	13.0	15.9	18.7	24.3	29.7	35.0	45.3	55.4	65.3	59.8	48.7	40.8	34.9	26.5
15	7.215	1.91	3.57	5.14	8.15	11.7	15.2	18.6	21.9	28.3	34.7	40.8	52.9	64.6	76.1	71.8	60.4	50.6	43.2	32.9
17	8.164	2.19	4.09	5.88	9.31	13.4	17.4	21.3	25.0	32.4	39.7	46.7	60.5	74.0	87.2	89.0	72.8	61.0	52.1	39.6
19	9.114	2.47	4.61	6.64	10.5	15.2	19.6	24.0	28.2	36.5	44.8	52.7	68.3	83.4	98.3	105	86.1	72.1	61.6	46.8
21	10.064	2.75	5.13	7.39	11.7	16.9	21.8	26.7	31.4	40.7	49.8	58.7	76.0	93.0	110	122	100	83.8	71.6	54.4
Lubrication #		Type I	Type II						Type III				Type IV							

Small Sprocket		HP RATINGS – STANDARD SINGLE* STRAND ROLLER CHAIN – NO. 140 – 1 3/4" PITCH															
RPM → Teeth	P.D.	10	20	30	50	75	100	125	150	200	250	300	400	500	600	700	800	900
11	6.211"	2.13	3.97	5.72	9.06	13.1	16.9	20.7	24.4	31.5	38.6	45.5	58.9	72.0	65.8	52.4	42.9	35.9
13	7.312	2.55	4.74	6.83	10.9	15.6	20.3	24.7	29.2	37.8	46.2	54.4	70.5	86.2	84.6	67.3	55.1	46.2
15	8.417	2.98	5.56	8.01	12.7	18.3	23.7	28.9	34.1	44.1	54.0	63.6	82.4	101	105	83.4	68.3	57.2
17	9.523	3.41	6.36	9.16	14.5	20.9	27.1	33.1	39.0	50.5	61.7	72.8	94.2	115	126	100	82.4	69.1
19	10.632	3.84	7.17	10.3	16.0	23.5	30.5	37.3	44.0	57.0	70.0	82.1	106	130	149	119	97.4	81.6
21	11.742	4.28	7.98	11.5	18.2	26.2	34.0	41.5	49.0	63.4	77.6	91.4	118	145	171	138	113	94.8
Lubrication #		Type I		Type II			Type III						Type IV					

Small Sprocket		HP RATINGS – STANDARD SINGLE* STRAND ROLLER CHAIN – NO. 160 – 2" PITCH														
RPM → Teeth	P.D.	10	20	30	50	75	100	125	150	200	250	300	400	500	550	600
11	7.099"	3.07	5.74	8.26	13.1	18.8	24.4	29.8	35.1	45.5	55.6	65.5	84.9	96.7	83.9	71.5
13	8.357	3.67	6.85	9.86	15.7	22.5	29.2	35.6	42.0	54.4	66.6	78.4	102	124	108	94.4
15	9.620	4.28	8.00	11.5	18.3	26.3	34.1	41.7	49.0	63.5	77.7	91.5	119	145	134	117
17	10.884	4.90	9.16	13.2	20.9	30.1	39.0	47.7	56.1	72.7	88.9	105	136	166	161	141
19	12.148	5.53	10.3	14.9	23.6	33.9	44.0	53.8	63.2	82.0	100	118	153	188	190	166
21	13.419	6.16	11.5	16.6	26.3	37.8	49.0	59.9	70.5	91.4	112	132	171	209	220	194
Lubrication #		Type I	Type II		Type III						Type IV					

RATINGS FOR INTERMEDIATE NUMBERS OF TEETH OR RPM MAY BE OBTAINED BY INTERPOLATION.

Courtesy of Boston Gear/Incom International Inc.

ASSIGNMENT SHEET #8

Table 6
Speed Ratio Chart

SPEED RATIOS – CENTER DISTANCES – CHAIN LENGTHS

Teeth on DriveR Sprocket		Teeth on DriveN Sprocket								
		15	16	17	18	19	20	21	22	23
11	Ratio	1.36	1.45	1.55	1.64	1.73	1.82	1.91	2.00	2.09
	CD*	6.469	7.207	7.943	7.669	8.404	8.124	8.857	9.590	9.304
	Length*	26	28	30	30	32	32	34	36	36
12	Ratio	1.25	1.33	1.42	1.50	1.58	1.67	1.75	1.83	1.92
	CD*	7.235	6.973	7.710	8.446	8.174	8.909	8.632	9.365	10.098
	Length*	28	28	30	32	32	34	34	36	38
13	Ratio	1.15	1.23	1.31	1.38	1.46	1.54	1.61	1.69	1.77
	CD*	6.993	7.736	7.473	8.212	8.949	8.679	9.414	9.139	9.872
	Length*	28	30	30	32	34	34	36	36	38
14	Ratio	1.07	1.14	1.21	1.29	1.36	1.43	1.50	1.57	1.64
	CD*	7.248	7.494	8.237	7.979	8.714	9.452	9.183	9.918	9.643
	Length*	30	30	32	32	34	36	36	38	38
15	Ratio	1.00	1.07	1.13	1.20	1.27	1.33	1.40	1.47	1.53
	CD*	7.500	8.248	7.994	8.737	8.477	9.216	9.955	9.686	10.422
	Length*	30	32	32	34	34	36	38	38	40
16	Ratio		1.00	1.06	1.13	1.19	1.25	1.31	1.37	1.44
	CD*		8.000	8.749	8.493	9.238	8.978	9.718	10.457	10.189
	Length*		32	34	34	36	36	38	40	40
17	Ratio			1.00	1.06	1.12	1.18	1.24	1.29	1.35
	CD*			8.500	9.249	8.998	9.739	9.479	10.220	10.959
	Length*			34	36	36	38	38	40	42
18	Ratio				1.00	1.06	1.11	1.17	1.22	1.28
	CD*				9.000	8.749	9.493	10.239	9.980	10.721
	Length*				36	36	38	40	40	42
19	Ratio					1.00	1.05	1.11	1.16	1.21
	CD*					9.500	10.249	9.998	10.740	10.481
	Length*					38	40	40	42	42
20	Ratio						1.00	1.05	1.10	1.15
	CD*						10.000	10.749	10.496	11.240
	Length*						40	42	42	44
21	Ratio							1.00	1.05	1.10
	CD*							10.500	11.249	10.996
	Length*							42	44	44
22	Ratio								1.00	1.05
	CD*								11.000	11.749
	Length*								44	46
23	Ratio									1.00
	CD*									11.500
	Length*									46
24										
25										

*Center Distance (CD) and Chain Length are in PITCHES. To obtain corresponding values in INCHES, multiply by the appropriate Chain Pitch.

Courtesy of Boston Gear/Incom International Inc.

ASSIGNMENT SHEET #8
Table 6 (Continued)
Speed Ratio Chart

SPEED RATIOS – CENTER DISTANCES – CHAIN LENGTHS

SPEED RATIOS – CENTER DISTANCES – CHAIN LENGTHS

Teeth on DriveR Sprocket		Teeth on DriveN Sprocket																	
		24	25	30	32	35	36	40	42	45	48	54	60	70	72	80	84	96	112
11	Ratio	2.18	2.27	2.72	2.91	3.18	3.27	3.64	3.82	4.09	4.36	4.91	5.45			*Center Distance (CD) and Chain Length are in PITCHES. To obtain corresponding values in INCHES multiply by the appropriate Chain Pitch.			
	CD*	10.037	9.744	11.345	12.812	14.976	15.668	15.561	15.983	17.139	18.294	19.539	21.843						
	Length*	38	38	44	48	52	52	58	60	64	68	74	82						
12	Ratio	2.00	2.08	2.50	2.66	2.92	3.00	3.33	3.50	3.75	4.00	4.50	5.00	5.83	6.00				
	CD*	9.815	10.547	12.161	12.597	13.761	14.495	15.349	15.723	16.930	18.085	20.396	21.637	25.834	26.244				
	Length*	38	40	46	48	52	54	58	60	64	68	76	82	96	98				
13	Ratio	1.85	1.92	2.31	2.46	2.69	2.77	3.08	3.23	3.46	3.69	4.15	4.61	5.39	5.54				
	CD*	10.605	10.324	11.943	12.379	13.546	14.229	15.136	16.605	16.719	18.925	20.186	22.496	25.628	26.038				
	Length*	40	40	46	48	52	54	58	62	64	70	76	84	96	98				
14	Ratio	1.72	1.79	2.14	2.28	2.50	2.57	2.86	3.00	3.22	3.43	3.86	4.29	5.00	5.14	5.71	6.00		
	CD*	10.378	11.112	12.746	13.188	[illegible]	14.063	[illegible]	16.391	17.553	18.713	19.977	22.287	25.422	25.834	28.545	30.439		
	Length*	40	42	48	50	54	54	60	62	66	70	76	84	96	98	108	114		
15	Ratio	1.60	1.67	2.00	2.14	2.33	2.40	2.67	[illegible]	3.00	3.20	3.60	4.00	4.67	4.80	5.33	5.60		
	CD*	10.150	10.884	12.522	12.967	14.141	14.874	15.746	16.177	17.340	18.500	20.819	22.079	26.279	26.694	29.413	30.234		
	Length*	40	42	48	50	54	56	60	62	66	70	78	84	98	100	110	114		
16	Ratio	1.50	1.56	1.88	2.00	2.19	2.25	2.50	2.62	2.81	3.00	3.38	3.75	4.37	4.50	5.00	5.25	6.00	
	CD*	10.926	10.654	12.299	13.768	13.921	14.653	15.528	16.994	18.161	18.287	20.607	22.923	26.071	26.487	29.206	31.098	34.633	
	Length*	42	42	48	52	54	56	60	64	68	70	78	86	98	100	110	116	130	
17	Ratio	1.41	1.47	1.76	1.88	2.06	2.12	2.35	2.47	2.65	2.82	3.18	3.53	4.12	4.24	4.70	4.94	5.64	
	CD*	10.692	11.429	13.087	13.539	14.721	14.433	16.349	[illegible]	17.945	19.110	20.395	22.712	25.863	27.337	29.000	30.891	34.429	
	Length*	42	44	50	52	56	56	62	64	68	72	78	86	98	102	110	116	130	
18	Ratio	1.33	1.39	1.67	1.78	1.94	2.00	2.22	2.34	2.50	2.67	3.00	3.33	3.89	4.00	4.44	4.66	5.33	
	CD*	11.461	11.195	12.858	13.314	14.497	15.230	16.119	16.557	17.728	18.894	21.223	22.501	26.708	27.128	29.855	30.685	35.295	
	Length*	44	44	50	52	56	58	62	64	68	72	80	86	100	102	112	116	132	
19	Ratio	1.26	1.31	1.58	1.68	1.84	1.89	2.10	2.21	2.37	2.52	2.84	3.16	3.68	3.79	4.21	4.41	5.05	5.90
	CD*	11.222	11.963	13.638	14.099	15.258	15.006	16.920	17.364	18.536	[illegible]	21.008	23.332	26.498	26.918	[illegible]	31.539	35.088	40.516
	Length*	44	46	52	54	58	58	64	66	70	72	80	88	100	102	112	[illegible]	132	152
20	Ratio	1.20	1.25	1.50	1.60	1.75	1.80	2.00	2.10	2.25	2.40	2.70	3.00	3.50	3.60	4.00	4.20	4.80	5.60
	CD*	10.982	11.723	13.406	13.869	15.061	15.795	16.697	17.142	18.317	19.489	21.827	23.119	26.287	27.258	30.493	31.330	34.882	40.312
	Length*	44	46	52	54	[illegible]	60	64	66	70	74	82	88	100	104	114	118	132	152
21	Ratio	1.14	1.19	1.43	1.52	1.67	1.71	1.90	2.00	2.14	2.28	2.57	2.86	3.33	3.43	3.81	4.00	4.57	5.33
	CD*	11.741	11.483	13.172	14.646	14.833	15.567	16.473	17.939	18.096	19.270	21.609	23.492	27.121	27.547	30.283	31.122	35.738	41.177
	Length*	46	46	52	56	58	60	64	68	70	74	82	90	102	104	114	118	134	154
22	Ratio	1.09	1.14	1.36	1.45	1.59	1.64	1.82	1.91	2.04	2.18	2.46	2.73	3.18	3.27	3.64	3.82	4.36	5.09
	CD*	11.496	12.231	13.942	14.413	15.613	15.338	17.202	17.714	18.895	20.073	21.392	[illegible]	26.910	27.334	30.073	31.965	35.331	40.971
	Length*	46	48	54	56	60	60	66	[illegible]	72	76	82	90	102	104	114	120	134	154
23	Ratio	1.04	[illegible]	1.30	1.39	1.52	1.56	1.74	1.83	1.96	2.08	2.34	2.61	3.04	3.13	3.48	3.65	4.17	4.87
	CD*	12.249	11.956	13.705	14.178	15.382	16.117	17.035	17.489	18.671	18.829	22.200	23.510	26.695	28.164	30.910	31.755	35.322	40.765
	Length*	48	48	54	56	60	62	66	68	72	74	84	90	102	106	116	120	134	154
24	Ratio	1.00	1.04	1.25	1.33	1.46	1.50	1.67	1.75	1.88	2.00	2.25	2.50	2.92	3.00	3.33	3.50	4.00	4.67
	CD*	12.000	12.750	14.469	14.946	16.155	[illegible]	17.818	[illegible]	19.463	19.628	21.980	24.323	27.522	27.951	30.699	31.544	36.170	41.622
	Length*	48	50	56	58	[illegible]	62	68	70	74	76	84	92	104	106	118	120	136	156
25	Ratio		1.00	1.20	1.28	1.40	1.44	1.60	1.68	1.80	1.92	2.16	2.40	2.80	2.88	3.20	3.36	3.84	4.48
	CD*		12.500	14.228	14.708	[illegible]	16.658	17.588	18.042	19.237	20.422	21.760	24.104	27.306	27.736	30.486	32.380	35.960	41.414
	Length*		50	56	58	62	64	68	70	74	78	84	92	104	106	116	122	136	156

Courtesy of Boston Gear/Incom International Inc.

POWER TRANSMISSION
UNIT XI

ASSIGNMENT SHEET #9—SELECT A V-BELT DRIVE

Directions: Using the tables included in Transparencies 1, 2, and 3, select V-belt drives for the problems which follow. An example is included to be used as a guideline for solving the problems.

Example problem: 1/3 HP, 1750 RPM motor for a drill press having a spindle speed of 1000 RPM. Center to center distance 20". Type belt needed is V-belt.

Example solution:

1. Decide whether belt will be used on light, normal, or heavy duty equipment; a drill press for this example is normal duty so use normal duty tables

   (NOTE: If equipment is light duty, multiply horsepower rating by 1.20. If it is heavy duty, multiply by .85.)

2. Select outside diameter of small V-pulley
   a. Using table on Transparency 1, go across from 1750 RPM to the .38 column; the .38 is a conversion from 1/3 HP; that is, 1/3 = .33 and .38 is closest to .33
   b. Read up from .38 to the top of the column to get 2.50" outside diameter of the small V-pulley for the motor
   c. Since the background area is white, the belt cross section is "A", 1/2" wide by 5/16" thick

3. Select driven V-pulley diameter
   a. Using table on Transparency 2 under "Driven Speeds for 1750 RPM Motors", read across the top row until the 2.50" column is reached; the 2.50" is the outside diameter of the small V-pulley for the motor
   b. Read down the 2.50" column until you come to the nearest RPM of the desired speed of 1000 RPM; the nearest RPM to 1000 RPM is 1050 RPM
   c. Read in the row to the left of the 1050 RPM until you come to the first column entitled "DriveN V-Pulley O.D. inches"; your answer is 4.0"; the 4.0" is the outside diameter of the driven v-pulley

4. Determine belt length
   a. Add the diameters of the small pulley and the driven (larger) pulley

      2.5 + 4.0 = 6.5

   b. Using table on Transparency 3, select the number on the top row of the table closest to the sum of 6.5; your selection should be 6 1/2"

ASSIGNMENT SHEET #9

c. Read down the 6 1/2" column to the first number just below the shaded area; this number is the ideal center to center distance of 6.8"

d. Read across the row to the left of 6.8" to column "Belt Length" which gives you a 24" belt length; the 24" belt length would be the ideal belt length

e. Our problem has a center to center distance of 20"; proceed down the 6 1/2" column to the closest to 20", which is the 19.9"

f. Read across the top to the left of the 19.9" to find the belt length of 50"

Problems:

A. A one horsepower, 1160 RPM motor is to operate a generator. The generator is connected to a pulley by a V-belt. The generator pulley must rotate approximately 600 RPM. The center to center distance is to be 14". Calculate the size of the V-belt required.

B. A 1750 RPM, 3/4 horsepower motor is used to drive a 500 RPM flywheel connected to a punch press. Center to center distance is 17". The motor pulley is connected to a pulley on the flywheel shaft. Calculate the size of the V-belt required.

POWER TRANSMISSION
UNIT XI

ASSIGNMENT SHEET #10--SELECT TYPES OF BEARINGS FROM HANDBOOKS

Directions: Select types of bearings for the following problems using available bearing handbooks and the table included at the end of this assignment sheet. An example is given to be used as a guideline for solving the problems. The following is a list of general considerations for selecting bearings.

1. Choose roller bearings for larger sizes and heavier loads because they are less expensive than ball bearings.
2. Choose ball bearings for smaller sizes and lighter loads because they are less expensive than roller bearings.
3. Under shock or impact loading, roller bearings are more satisfactory than ball bearings.
4. Use a self-aligning or spherical roller bearing when there is misalignment between housing and shaft.
5. Ball thrust bearings should be used for pure thrust loads only.
6. Use a deep groove or angular contact ball bearing for high speeds of pure thrust loads.
7. For long operating periods without attention, the deep groove ball bearing is available with seals built into the bearings.

Example problem: Select a light inch ball bearing from a handbook that would satisfy the following design needs:

1. Maximum speed = 5800 RPM
2. Dynamic load rating = 3400 lbs.
3. Static load rating = 1800 lbs.

What is the bore size and outside diameter size?

(NOTE: Experience has shown that actual failure of ball bearings has been due to fatigue. Calculation of rating life, basic load rating, and other factors will be found in a machine design class.)

Example solution:

1. Locate light inch ball bearings from mechanical components handbook or Table 1
2. Read down the limiting speed column for 5800 RPM; notice it falls between 5600 and 6300
3. Choose 6300 RPM which is LS 13 1/2

ASSIGNMENT SHEET #10

4. Read down the dynamic load rating column for 3400 lbs.; notice it falls between 3350 and 4050 lbs

5. Choose 4050 lbs. which is LS 12

6. Read down the static load rating column for 1800 lbs. which is LS 10

7. Decide which bearing will satisfy the extreme condition and yet satisfy the other conditions

   a. Choose the largest load either dynamic or static as the controlling factor

   b. The LS 12 bearing number at 4050 lbs. dynamic load is chosen

   c. The 1800 lb. static load is within the static load rating of 2750 lbs.

   d. The limiting speed of 8000 RPM covers the 5800 RPM expected speed

8. Bore size is 1 1/4"; outside diameter is 2 3/4"

Problems:

A. Select a light inch ball bearing from a handbook that would satisfy the following design needs:

   1. Maximum speed = 3400 RPM

   2. Dynamic load rating = 7500 lbs.

   3. Static load rating = 9150 lbs.

   What is the bore size and outside diameter size? ______________________

B. Select a light inch ball bearing from a handbook that would satisfy the following design needs:

   1. Maximum speed = 2200 RPM

   2. Dynamic load rating = 4800 lbs.

   3. Static load rating = 1375 lbs.

   What is the bore size and outside diameter size? ______________________

ASSIGNMENT SHEET #10

Table 1
Light Inch Ball Bearings

BEARING NUMBER* Norma FAG	BOUNDARY DIMENSIONS inch BORE	O. DIAM.	WIDTH	MAX FILLET RADIUS Shaft & Housing inch	APPROX WEIGHT lb.	S_l LIMITING SPEED rpm	C DYNAMIC LOAD RATING lb.	C_o STATIC LOAD RATING lb.
LS 5	½	1 5/16	⅜	.020	.12	22000	1180	695
LS 7	⅝	1 9/16	7/16	.020	.15	16000	1660	1000
LS 8	¾	1⅞	9/16	.040	.27	14000	2200	1370
LS 9	⅞	2	9/16	.040	.32	12000	2240	1370
LS 10	1	2¼	⅝	.040	.42	11000	2800	1800
LS 11	1⅛	2½	⅝	.040	.51	9000	3350	2240
LS 12	1¼	2¾	11/16	.040	.63	8000	4050	2750
LS 12½	1⅜	3	11/16	.040	.86	7100	4400	3100
LS 13	1½	3¼	¾	.060	1.10	7100	5500	3800
LS 13½	1⅝	3½	¾	.060	1.29	6300	5600	4000
LS 14	1¾	3¾	13/16	.060	1.61	5600	6300	4650
LS 14½	1⅞	4	13/16	.060	1.85	5600	7500	5600
LS 15	2	4	13/16	.060	1.78	5600	7500	5600
LS 16	2¼	4½	⅞	.060	2.40	5000	9150	6950
LS 17	2½	5	15/16	.060	3.15	4500	10800	8500
LS 18	2¾	5¼	15/16	.060	3.40	4000	11400	9150
LS 19	3	5¾	1 1/16	.060	4.65	3600	12500	9800
LS 19½	3¼	6	1 1/16	.060	4.90	3600	14300	11800
LS 20	3½	6½	1⅛	.080	6.20	3200	16000	13200
LS 20½	3¾	6¾	1⅛	.080	6.70	3200	18600	15600
LS 21	4	7¼	1¼	.080	8.80	2800	19600	17600
LS 21½	4¼	7½	1¼	.080	9.15	2800	22800	20000
LS 22	4½	8	1 5/16	.080	11.20	2500	24500	22400
LS 22½	4¾	8¼	1 5/16	.080	11.40	2500	25000	22800
LS 23	5	9	1⅜	.080	15.00	2200	26500	24500
LS 23½	5½	9½	1⅜	.080	15.60	2200	28000	27000
LS 24	6	10½	1 9/16	.10	22.60	2000	32000	32500
LS 24½	6½	11	1 9/16	.10	24.00	1800	33500	35500
LS 25	7	12	1¾	.10	36.50	1800	35500	39000
LS 25½	7½	12½	1¾	.10	46.00	1600	35500	39000
LS 26	8	13	1¾	.10	57.00	1600	36500	42500

Courtesy of FAG Bearings Corporation

POWER TRANSMISSION
UNIT XI

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. Drawing evaluated to the satisfaction of the instructor
Chordal addendum = .575
B. Drawing evaluated to the satisfaction of the instructor
Pitch diameter = 12
Whole depth = .2697
Chordal addendum = .2008

Assignment Sheet #2

A. Drawing evaluated to the satisfaction of the instructor
B.

CUTTING DATA		
	Gear	Pinion
Number of teeth	30	20
Diametral Pitch	5	
Pressure angle	14 1/2°	
Whole depth	.4314	
Root angle	52.6°	30.4°
Face angle	59.5°	36.9°
Chordal Thickness	.314	.314
Addendum	.2	

Assignment Sheet #3

A. Drawing evaluated to the satisfaction of the instructor
Whole depth = .343
Face length = 2.61
B. Drawing evaluated to the satisfaction of the instructor
Throat diameter = 6.048
Pitch diameter = 5.730
Rim radius = 1.650 R

Assignment Sheet #4

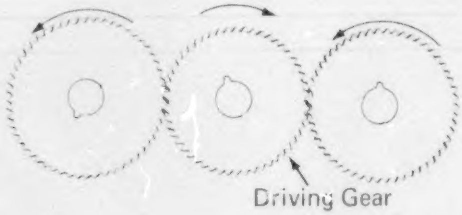
A.
1. .25:1
2. .75:1
3. 3:1
4. 5:1

ANSWERS TO ASSIGNMENT SHEETS

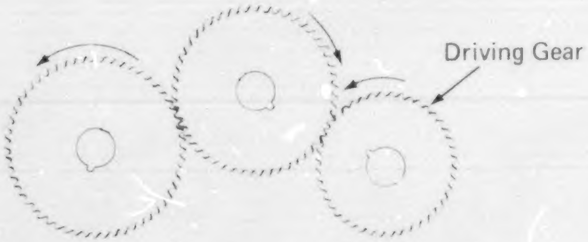
B.
1. .55:1
2. 1.82:1
3. 4:11:1
4. 5.70:1
5. 5.11:1
6. 5.09:1

Assignment Sheet #5

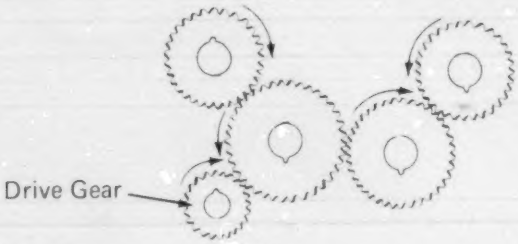
A.


Driving Gear

B.


Driving Gear

C.



Assignment Sheet #6

		Rotation	Ratio	R.P.M.
A.	Gear A	CC	2:1	1800
B.	Gear B	C	.33:1	5400
C.	Gear C	C	.80:1	2250
D.	Gear D	CC	.83:1	2700

		Rotation	Ratio	R.P.M.
E.	Gear E	CC	.16:1	7200
F.	Gear F	CC	.40:1	3000
G.	Gear G	C	.83:1	3600
H.	Gear H	CC	.50:1	2400

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #7--Evaluated to the satisfaction of the instructor

Assignment Sheet #8

A.
1. Load classification--uniform
2. Service factor = 1
   Input power--5 x 1 = 5 HP
3. Using 100 RPM and 5 HP, select chain #80 from Chain selection table
4. On HP Rating table and using 100 RPM and interpolation, select 16 teeth. 5 HP is approximately halfway between 4.70 (15 teeth) and 5.38 (17 teeth)
5. Speed ratio - $\frac{100}{40} = 2.5$
6. Larger sprocket 16 x 2.5 = 40 teeth or use Speed ratio table
7. Answer is 15.528 center distance in pitch
   60 chain length in pitches
8. Convert to inches
   15.528 (1) = 15.528" center distance
   60 (1) = 60" chain length
9. 15.528" center distance is within the 27" center distance limitation

B.
1. Load classification under pumps rotary gear type--uniform load
2. Service factor = 1
   Input power--3 x 1
3. Chain selection table using 3 HP and 1200 RPM, select #35--3/8" pitch chain number
4. Using 1200 RPM and 3 HP, select 19 teeth from HP ratings table
5. Speed ratio -- $\frac{1200}{750} = 1.60$
6. Larger sprocket 19 x 1.60 = 30.4 or use speed ratio table for similar results, and select 30 teeth
7. Answer is 13.638 center distance in pitches
   52 chain length in pitches
8. Convert to inches
   13.638 (.375) = 5.115" center distance
   52 (.375) = 19.5" chain length
9. 19.5 center distance is not less than 12" center distance limitation

Assignment Sheet #9

A.
1. Classification: normal duty
2. Using Transparency 1, go across from 1160 RPM of small pulley to .98 column; the .98 is a conversion from 1 HP; that is, 1 HP is closest to .98 HP
3. Read up from .98 to the top; select 4.25" outside diameter of small pulley
4. Since the background area is darker, use cross section B - $\frac{21}{32}$ wide by $\frac{13}{32}$ thick
5. Using Transparency 2 under 1160 RPM motors, read across the top until 4.25 column is reached
6. Read down 4.25 column to the nearest RPM of the desired speed of 600 RPM which is 599 RPM
7. Read in the row to the left of the 599 RPM until you reach 8.0" O.D. of Drive N V-Pulley

8. Add the diameters of the small pulley and the driven pulley--4.25 + 8 = 25.25"
9. Using table on Transparency 3, select the number on the top row of the table closest to the sum of 12.25; use 12 1/2
10. Read down the 12 1/2 column to the number closest to the center to center distance of 14"
11. Using 13.9", read to the left over to belt length column of 48"

B.
1. Classification: heavy duty--multiply horsepower by .85, then use normal duty tables; .85 x .75 = .64 HP; the .75 HP is a conversion of 3/4 HP.
2. Using Transparency 1 go across from 1750 RPM of small pulley to .63 HP; that is, .63 HP is closest to .64 HP
3. Read up from .63 to the top and select 3.00" outside diameter of small pulley
4. Since the background area is white area, use cross section A - 1/2" wide by 5/16" thick
5. Using Transparency 2 under 1750 RPM motors, read across the top until 3.00 column is reached.
6. Read down 3.00 column to the nearest RPM of the desired speed of 500 RPM which is .474 RPM
7. Read in the row to the left of the 474 RPM until you reach 7.0 OD of Drive N V-Pulley
8. Add the diameters of the small pulley and the driven pulley; 3.00 + 7.00 = 10.00
9. Using table on Transparency 3, select the number on the top row of the table closest to the sum of 10.00; use 10
10. Read down the 10 column to the closest center to center distance of 17 inches; use 17.1
11. Using 17.1", read to the left over to belt length column of 50"

Assignment Sheet #10

A.
1. Limiting speed 3600 RPM
2. Dynamic load rating 7500 lbs.
3. Static load rating 9150 lbs.
4. Select 9150 lb. static load as controlling factor--LS16
5. The 11400 lb. dynamic limit will cover the 7500 lb. design load
6. The 4000 RPM will cover the 3600 RPM design load
7. LS16 bore size = 2 3/4"; outside diameter = 5 1/4"

B.
1. Limiting speed 2200 RPM
2. Dynamic load rating 5500 lbs
3. Static load rating 1800
4. Select the 5500 lbs. as controlling factor--LS13
5. The 3800 lb. static load will cover the 1800 lb. design load
6. The 7100 RPM limiting speed will cover the 2200 RPM design load
7. LS13 bore size = 1 1/2"; outside diameter = 3 1/4"

POWER TRANSMISSION
UNIT XI

NAME ________________________________

TEST

1. Match the terms on the right with the correct definitions.

______a. Machine parts used to lessen friction

______b. Devices for joining shafts together

______c. Compressed air is used as power transmission

______d. Toothed wheel meshing with another toothed wheel

______e. Devices used to transmit power around corners and different angles when the driver and driven shafts are not lined up

______f. Endless flexible belt on pulleys

______g. Liquid is used as power transmission

______h. Devices for slowing or stopping power driven shafts

______i. Motion and function generators

______j. Endless chain on sprockets

______k. Devices for stopping or starting a machine without stopping the prime mover

______l. Machine elements designed to produce a specific motion

______m. Any device used to reduce the speed of the output device

______n. A second motion or intermediate shaft in a power transmission system

______o. As a gear it serves to fill up space and reverse direction; as a pulley it serves to take up slack

______p. A liner forced in a hole to provide a better wearing or bearing surface and to provide for easy renewal

______q. Parts used to protect ball or roller bearings from loss of lubricant and entrance of dust and dirt on bearings

1. Gear drive
2. Belt drive
3. Chain drive
4. Countershaft
5. Couplings
6. Clutches
7. Gear reduction
8. Brakes
9. Splines
10. Flexible shafts
11. Speed reducer
12. Seals
13. Bearings
14. Cams
15. Linkages
16. Power train
17. Hydraulics
18. Pneumatics
19. Idler
20. Bushing
21. Gear ratio

______r. A combination of gears used to reduce the input speed to a lower output speed

______s. The number of revolutions the drive gear must make to turn the driven gear one revolution

______t. Revolving components involved in the transmission of power from the engine to the drive wheel

______u. Multiple keys in the general form of internal and external gear teeth, used to prevent rotation of a shaft

2. Distinguish between advantages of chain drives and gear drives by placing an "X" next to the advantages of chain drives and an "O" next to the advantages of gear drives.

______a. Better shock absorbing

______b. Higher RPM can be obtained

______c. Maximum speed ratio can be greater

______d. Wear is reduced

______e. Center to center distance is not restricted

______f. Generally more practical at higher RPM and higher horsepower

______g. Ease of changes in design

3. Distinguish between advantages of chain drives and belt drives by placing an "X" next to the advantages of chain drives and an "O" next to the advantages of belt drives.

______a. Lower loads on bearings due to slack

______b. Occupies less overall space

______c. Does not deteriorate with age

______d. Generally operates with less noise

______e. Easier to install

4. Arrange in order the steps for selecting a V-belt drive by placing the correct sequence numbers in the appropriate blanks.

______a. Select driven V-pulley diameter

______b. Select outside diameter of small V-pulley

______c. Decide whether belt will be used on light, normal, or heavy duty equipment

______d. Determine belt length

5. Complete the following list of major types of power transmission chains.

   a. ______________________________

   b. Offset sidebar

   c. Double pitch

   d. ______________________________

   e. Detachable

   f. ______________________________

   g. Inverted tooth

6. Match the axes positions on the right with the correct types of gears.

   ______a. Worm and worm gear

   ______b. Plain bevel gear

   ______c. Rack and pinion gear

   ______d. Planetary gear

   ______e. Spur gear

   ______f. Helical gear

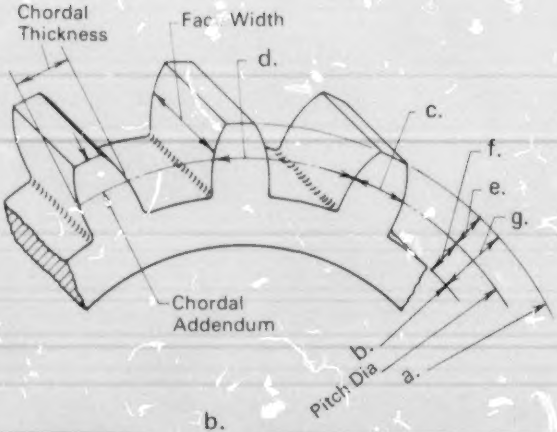
   1. Axes intersect

   2. Axes are parallel

   3. Axes do not intersect

   4. Axes do not intersect and straight line motion converts to circular motion and vice versa

7. Identify parts of gear teeth.


Chordal Thickness
Face Width
d.
c.
f.
e.
g.
Chordal Addendum
b.
Pitch Dia
a.

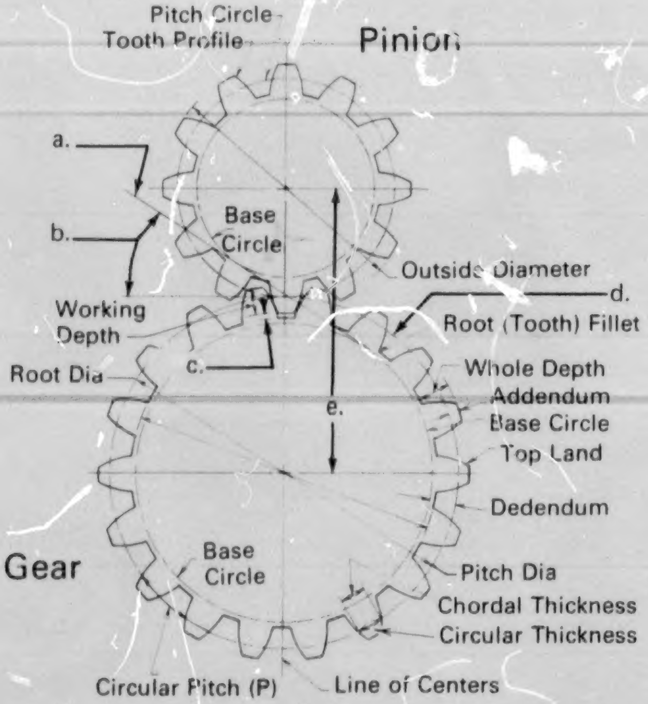
a. ______________________ b. ______________________

c. ______________________ d. ______________________

e. ______________________ f. ______________________

g. ______________________

8. Identify parts of pinion and gear.


Pitch Circle
Tooth Profile
Pinion
a.
b.
Base Circle
Outside Diameter
d.
Working Depth
Root (Tooth) Fillet
c.
Root Dia
Whole Depth
Addendum
Base Circle
e.
Top Land
Dedendum
Gear
Base Circle
Pitch Dia
Chordal Thickness
Circular Thickness
Circular Pitch (P)
Line of Centers

a. ______________________ b. ______________________

c. ______________________ d. ______________________

e. ______________________

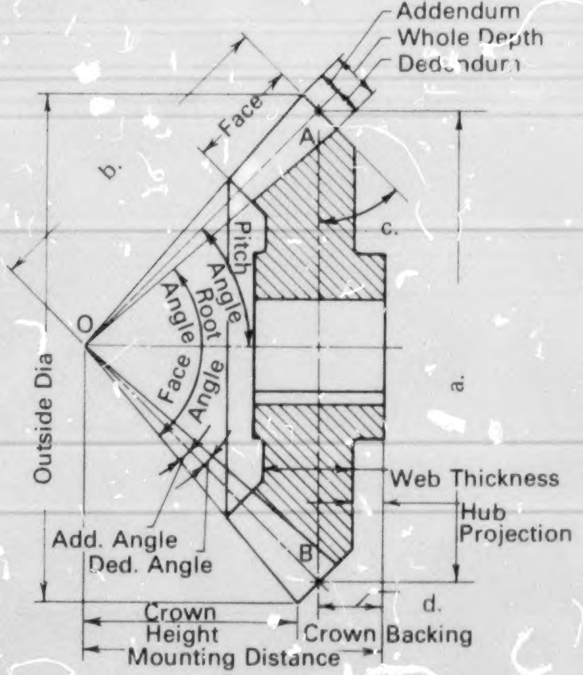
9. Name three types of cutting data needed for spur gear drawings.

a. ______________________________

b. ______________________________

c. ______________________________

10. Identify parts of a bevel gear.


Addendum
Whole Depth
Dedendum
Face
A
b.
c.
Pitch Angle
Root Angle
O
Face Angle
Outside Dia
a.
Web Thickness
Hub Projection
Add. Angle
Ded. Angle
B
d.
Crown Height
Crown Backing
Mounting Distance

a. ______________________ b. ______________________

c. ______________________ d. ______________________

11. Complete the following list of cutting data needed for bevel gears.

a. Number of teeth in pinion

b. ______________________________

c. Diametral pitch

d. Pressure angle

e. ______________________________

f. Root angle

g. Face angle

h. Whole depth

i. Chordal addendum for ____

j. Chordal addendum for ____

k. Chordal ____

12. Distinguish between cutting data needed for worm and cutting date needed for worm wheel by placing an "X" next to the cutting data needed for a worm and an "O" next to cutting data needed for a worm wheel.

______a. Number of teeth

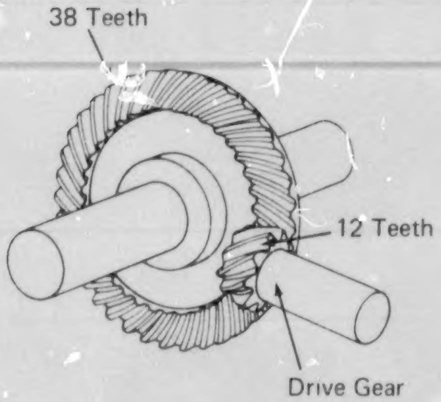
______b. Rim radius

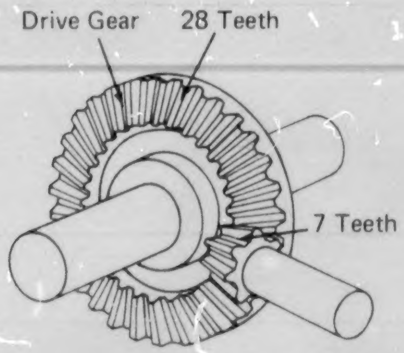
______c. Face length

______d. Throat diameter

13. Calculate the gear ratio of the gears below and write the correct answers in the blanks provided.

a. Driven gear has 64 teeth
Driving gear has 36 teeth ________________________________


38 Teeth
12 Teeth
Drive Gear


Drive Gear
28 Teeth
7 Teeth

b. ________________________________ c. ________________________________

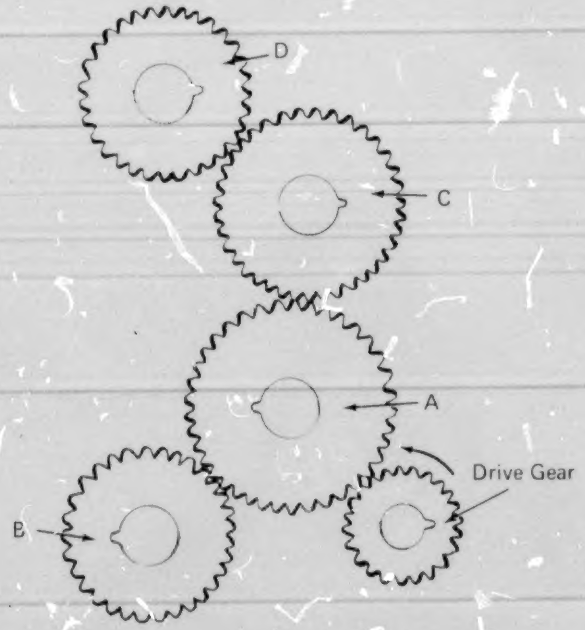
14. Determine gear rotation of the gears below by writing "C" for clockwise or "CC" for counterclockwise in the blanks provided.

______ a. Gear A

______ b. Gear B

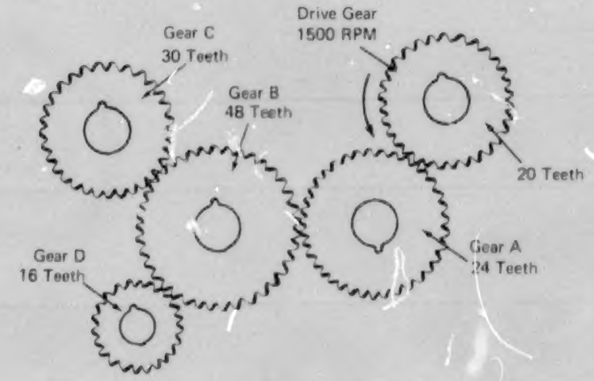
______ c. Gear C

______ d. Gear D


D
C
A
Drive Gear
B

15. Calculate gear speed and write the answers in the blanks provided.

		Rotation	Ratio	RPM
a.	Gear A	C	1.20:1	______
b.	Gear B	CC	2:1	______
c.	Gear C	C	.63:1	______
d.	Gear D	C	.33:1	______


Gear C
30 Teeth
Drive Gear
1500 RPM
Gear B
48 Teeth
20 Teeth
Gear A
24 Teeth
Gear D
16 Teeth

16. List two types of couplings.

a. ______________________________

b. ______________________________

17. Distinguish between types of bearings by placing an "X" next to the plain bearings and an "O" next to the antifriction bearings.

_____a. Ball

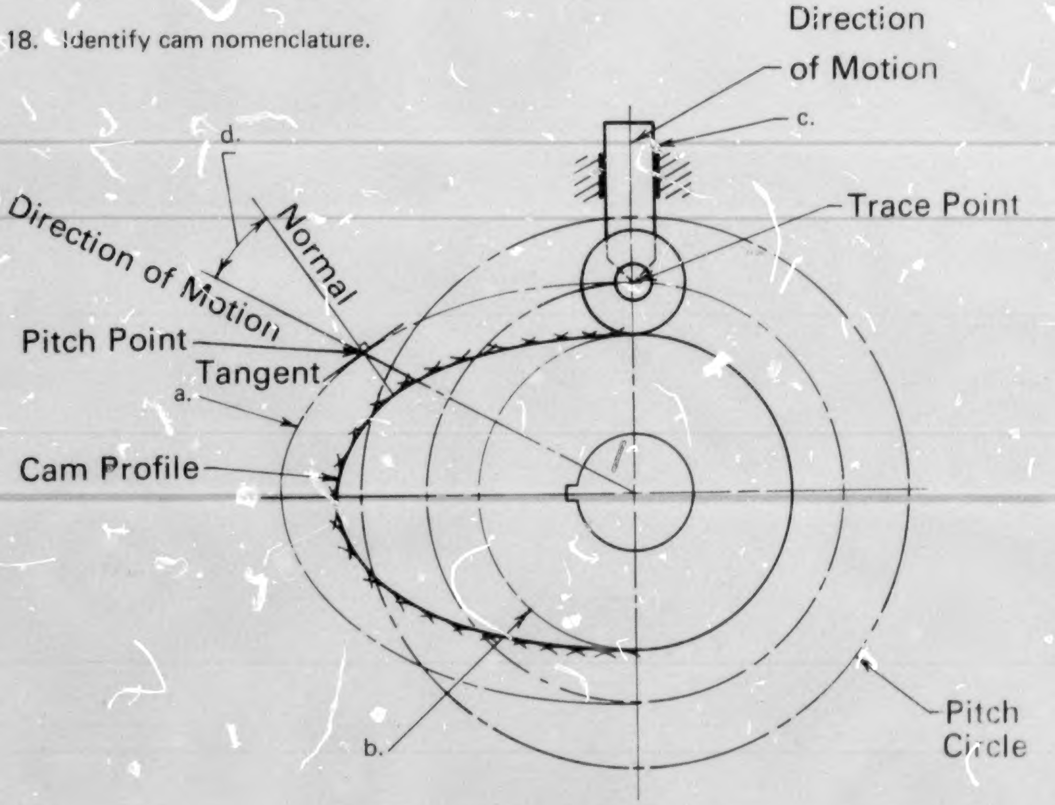
_____b. Radial

_____c. Thrust

_____d. Roller

_____e. Guide or slipper

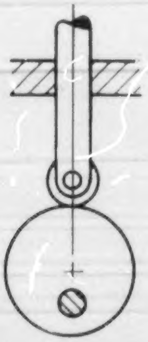
18. Identify cam nomenclature.


Direction of Motion
c.
d.
Trace Point
Direction of Motion
Normal
Pitch Point
Tangent
a.
Cam Profile
b.
Pitch Circle

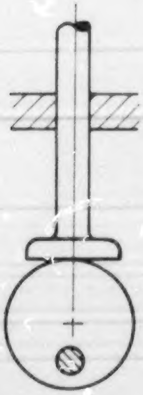
a. ____________________ b. ____________________

c. ____________________ d. ____________________

19. Identify types of cam followers.



a. ______________________________



b. ______________________________

20. Select types of cam motions by placing an "X" in the appropriate blanks.

______a. Modified

______b. Readjusted

______c. Parabolic, construction method

______d. Simplified

______e. Uniform

______f. Harmonic

21. Match hydraulic nomenclature on the right with the correct definitions.

______a. Device to convert fluid energy into mechanical force

______b. Instruments to measure pressure, temperature, or flow

______c. Reservoir to hold fluid

______d. Parts to control flow and pressure

______e. Device to force liquid through system

______f. Parts to clean fluid

______g. A cylinder in which fluid is stored under pressure and used to meet fluctuating demands

1. Tank
2. Pump
3. Valves
4. Cylinder or motor
5. Filters and strainers
6. Accumulator
7. Gages

22. Match basic pneumatic components on the right with the correct functions.

_____a. Compresses the air

_____b. Removes dirt and water

_____c. Lubricates the operating components of a system

_____d. Indicates pressure

_____e. Stores compressed air

_____f. Keeps air pressure within an acceptable range

1. Pressure gage
2. Filter
3. Regulator
4. Compressor
5. Receiving tank
6. Lubricator

23. Distinguish between air circuit components by placing an "X" next to the control elements and an "O" next to the power elements.

_____a. 3-position

_____b. Cylinders

_____c. Air motors

_____d. 2-way

24. Demonstrate the ability to:

a. Construct a spur gear drawing.

b. Construct a bevel gear.

c. Construct a worm and worm gear.

d. Calculate gear ratios.

e. Determine gear rotation.

f. Calculate gear speeds.

g. Construct a cam drawing.

h. Select a chain drive.

i. Select a V-belt drive.

j. Select types of bearings from handbooks.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

POWER TRANSMISSION
UNIT XI

ANSWERS TO TEST

1. a. 13
b. 5
c. 18
d. 1
e. 10
f. 2
g. 17
h. 8
i. 15
j. 3
k. 6
l. 14
m. 11
n. 4
o. 19
p. 20
q. 12
r. 7
s. 21
t. 16
u. 9

2. a. X
b. O
c. O
d. X
e. X
f. O
g. X

3. a. X
b. X
c. X
d. O
e. X

4. a. 3
b. 2
c. 1
d. 4

5. a. Roller
d. Pintle
f. Bead

6. a. 3
b. 1
c. 4
d. 2
e. 2
f. 2 or 3

7. a. Outside diameter
b. Root diameter
c. Circular thickness
d. Circular pitch
e. Addendum
f. Dedendum
g. Whole depth

8. a. Line of action
b. Pressure angle
c. Clearance
d. Pitch circle
e. Center distance

9. Any three of the following:

    a. Number of teeth
    b. Pitch diameter
    c. Diametral pitch
    d. Pressure angle
    e. Whole depth
    f. Chordal addendum
    g. Chordal thickness

10. a. Pitch diameter
    b. Cone distance
    c. Back angle
    d. Backing

11. b. Number of teeth in gear
    e. Addendum
    i. Pinion
    j. Gear
    k. Thickness

12. a. O
    b. O
    c. X
    d. O

13. a. 1.77:1
    b. 3.16:1
    c. .25:1

14. a. C
    b. CC
    c. CC
    d. C

15. a. 1250
    b. 625
    c. 1000
    d. 1875

16. a. Permanent
    b. Clutches

17. a. O
    b. X
    c. X or O
    d. O
    e. X

18. a. Pitch circle
    b. Base circle
    c. Follower
    d. Pressure angle

19. a. Roller
    b. Flat face

20. a, c, e, f

21.

a.	4	e.	2
b.	7	f.	5
c.	1	g.	6
d.	3		

22.

a.	4	d.	1
b.	2	e.	5
c.	6	f.	3

23. a. X
    b. O
    c. O
    d. X

24. Evaluated to the satisfaction of the instructor